Chapter 5: Costs of Control

This chapter describes our approach to estimating the cost of complying with emission standards. We start with a general description of the approach to estimating costs, then describe the technology changes we expect and assign costs to them. We also present an analysis of the estimated aggregate cost to society.

5.1 Methodology

We developed the costs for individual technologies using information provided by ICF, Incorporated and Arthur D. Little, as cited below with further consideration to any information provided in the public comments. The technology characterization and cost figures reflect our current best judgment based on engineering analysis, information from manufacturers, and the published literature. The analysis combines cost figures including markups to the retail level.

Costs of control include variable costs (for incremental hardware costs, assembly costs, and associated markups) and fixed costs (for tooling, R&D, and certification). Variable costs are marked up at a rate of 29 percent to account for the engine manufacturers' overhead and profit.[1] For technologies sold by a supplier to the engine manufacturers, an additional 29 percent markup is included for the supplier's overhead and profit. All costs are in 2001 dollars.

The analysis presents an estimate of costs that will occur in the first year of new emission standards and the corresponding long-term costs. Long-term costs decrease due to two principal factors. First, fixed costs are assessed for five years, after which they are fully amortized and are therefore no longer part of the cost calculation. Second, manufacturers are expected to learn over time to produce the engines with the new technologies at a lower cost. Because of relatively low sales volumes, manufacturers are less likely to put in the extra R&D effort for low-cost manufacturing. Learning will occur in two basic ways. As manufacturers produce more units, they will make improvements in production methods to improve efficiency. One example of this is automation. The second way learning occurs is materials learning where manufacturers reduce scrap. Scrap includes units that are produced but rejected due to inadequate quality and material scrap left over from the manufacturing process. As production starts, assemblers and production engineers will then be expected to find significant improvements in fine-tuning the designs and production processes. Consistent with analyses from other programs, we reduce estimated variable costs by 20 percent beginning with the third year of production and an additional 20 percent beginning with the sixth year of production.[2]

We believe it is appropriate to apply this factor here, given that the industries are facing emission regulations for the first time and it is reasonable to expect learning to occur with the experience of producing and improving emission-control technologies. Manufacturers do not have significant experience with most of the emissions controls that are anticipated for meeting the standards contained in the Final Rule. In cases where manufacturers have used certain technologies, such as with 4-stroke engines, they have not been required to meet standards. They will be manufacturing new 4-stroke engines or purchasing and installing 4-stroke engines in new models. Learning will likely occur for these models. Some manufacturers, especially in the youth ATV market do not have experience with 4-stroke engines. Also, the 4-strokes will need to be made to meet emissions standards. We believe that learning for these models will continue to take place.

Many of the engine technologies available to manufacturers to control emissions also have the potential to significantly improve engine performance. This is clear from the improvements in automotive technologies. As cars have continually improved emission controls, they have also greatly improved fuel economy, reliability, power, and a reduced reliance on regular maintenance. Similarly, the fuel economy improvements associated with converting from two-stroke to four-stroke engines is well understood. We attempt to quantify these expected improvements, as we describe for each type of engine below.

Even though the analysis does not reflect all the possible technology variations and options that are available to manufacturers, we believe the projections presented here provide cost estimates representative of the different approaches manufacturers may ultimately take. We expect manufacturers in many cases to find and develop approaches to achieve the emission standards at a lower cost than we describe in this analysis.

5.2 Cost of Emission Controls by Engine/Vehicle Type

5.2.1 Recreational Marine Diesel Engines

We have developed cost estimates for diesel engine technologies for several different applications in a series of reports.[3,4,5] This analysis adapts these existing cost estimates for recreational marine diesel engines with separate estimates for three different sizes of engines.

Recreational marine diesel engines invariably have counterpart engine models used for commercial application. Manufacturers will design, certify, and manufacture these commercial models to meet emission standards. The analysis projects that manufacturers will comply with the new emission standards generally by applying the same technologies for both commercial and recreational engines. The remaining effort to meet emission standards with the recreational models is therefore limited to applying new or improved hardware and conducting sufficient R&D to integrate the new technologies into marketable products. The analysis therefore does not consider fixed costs to develop the individual technologies separately.

One area where recreational engine designs differ is in turbocharging and aftercooling. To reach peak performance, recreational engines typically already use optimized turbochargers and seawater aftercooling, which offer the greatest potential for controlling NOx emissions.

We estimate the total cost impact of new emission standards by considering the cost of each of the anticipated technologies. The following paragraphs describe these technologies and their application to recreational marine engines. The analysis then combines these itemized costs into a composite estimate for the range of marine engines affected by the rulemaking.

Table 5.2.1-1 also includes information on product offerings and sales volumes, which is needed to calculate amortized fixed costs for individual engines. Estimated sales and product offerings were compiled from the PSR database based on historical 1997 information.

Table 5.2.1-1
Recreational Marine Diesel Engine Categories for Estimating Costs

Engine Power Ranges (kW)	Nominal Engine Power (kW)	Annual Sales	Models	Average Sales per Model
37 - 225	100	11,600	17	675
225 - 560	400	3,560	15	250
560 +	750	397	6	70

Manufacturers are expected to develop engine technologies not only to reduce emissions, but also to improve engine performance. While it is difficult to take into account the effect of ongoing technology development, EPA is concerned that assessing the full cost of the anticipated technologies as an impact of new emission standards inappropriately excludes from consideration the expected benefits for engine performance, fuel consumption, and durability.[1] Short of having sufficient data to predict the future with a reasonable degree of confidence, we face the need to devise an alternate approach to quantifying the true impact of the new emission standards. As an attempt to take this into account, we present the full cost of the control technologies in this chapter, then apply an adjustment to some of these costs for calculating the cost-per-ton of the emission standards, as described in Chapter 7.

5.2.1.1 Fuel Injection Improvements

All engines are expected to see significant improvements in their fuel injection systems. The smaller engines will likely undergo incremental improvements to existing unit injector designs. The analysis projects that engines rated over 600 kW will use common rail injection technology, which greatly increases the flexibility of tailoring the injection timing and profile to varying modes of operation. Better control of injection timing and increased injection pressure contribute to reduced emissions. Table 5.2.1-2 shows the estimated costs for these fuel injection improvements.

[1]While EPA does not anticipate widespread, marked improvements in fuel consumption, small improvements on some engines may occur.

Table 5.2.1-2: Fuel Injection Improvements

	100 kW	400 kW	750 kW
Component costs	$63	$98	$205
Assembly, markup, and warranty	$32	$46	$59
Composite Unit Cost	$95	$144	$264

5.2.1.2 Engine Modifications

Manufacturers will be optimizing basic engine parameters to control emissions while maintaining performance. Such variables include routing of the intake air, piston crown geometry, and placement and orientation of injectors and valves. Most of these variables affect the mixing of air and fuel in the combustion chamber. Small changes in injection timing are also considered in this set of modifications. We expect, however, that manufacturers will complete this work for commercial marine diesel engines, so that the remaining effort will be focused on fine-tuning designs for turbocharger matching and other calibration-related changes. Fixed costs are amortized over a five-year period, using the sales volumes developed in Table 5.2.1-1, with forward discounting incorporated to account for manufacturers incurring these costs before the emission standards begin to apply. Table 5.2.1-3 shows the estimated per-engine costs for these modifications. These costs include the consideration manufacturers must give to offsetting any crankcase emissions routed to the exhaust. There is no estimated long-term cost to the engine modifications because manufacturers can fully recover the fixed costs, and we don't expect any increase in variable costs as a result of these improvements.

Table 5.2.1-3: Engine Modifications

	100 kW	400 kW	750 kW
Total fixed costs	$200,000	$200,000	$200,000
Fixed cost per engine	$72	$195	$697
Composite Unit Cost	$72	$195	$697

As described in the preamble to the final rule, the manufacturers are responsible to comply with emissions at any speed and load that can occur on a vessel. We believe that is not appropriate to consider additional costs for manufacturers to comply with these "off-cycle" requirements. This is because we expect that manufacturers can manage engine operation to avoid unacceptable variation in emission levels by more effectively using the technologies that will be used to meet the emission limits more broadly, rather than by use of additional hardware. For example, manufacturers can adjust fuel injection parameters to avoid excessive emissions. The split-zone approach described in Chapter 4 is designed to accommodate normal variation in emission levels at different operating points. This approach involves no additional variable cost.

The estimated R&D expenditures reflect the time needed to address this.

5.2.1.3 Certification and Compliance

We have significantly reduced certification procedural requirements in recent years, but manufacturers are nevertheless responsible for generating the necessary test data and other information to demonstrate compliance with emission standards. Table 5.2.1-4 lists the expected costs for different sizes of engines, including the amortization of those costs over five years of engine sales. Estimated certification costs are based on two engine tests and $10,000 worth of engineering and clerical effort to prepare and submit the required information.

Until engine designs are significantly changed, engine families can be recertified each year using carryover of the original test data. Since these engines are currently not subject to any emission requirements, the analysis includes a cost to recertify an upgraded engine model every five years.

Costs for production line testing are summarized in Table 5.2.1-5. These costs are based on testing 1 percent of total estimated sales, then distributing costs over the fleet. Listed costs for engine testing presume no need to build new test facilities, since we may waive production-line testing requirements for small-volume production. Few manufacturers, if any, will therefore need to build new test facilities.

Table 5.2.1-4: Certification

	100 kW	400 kW	750 kW
Total fixed costs	$30,000	$30,000	$40,000
Fixed cost per engine	$12	$29	$139
Composite Unit Cost	$12	$29	$139

Table 5.2.1-5: Costs for Production Line Testing

	100 kW	400 kW	750 kW
Cost per test	$10,000	$10,000	$15,000
Testing rate	1 %	1 %	1 %
Cost per engine	$100	$100	$150

5.2.1.4 Total Engine Costs

These individual cost elements can be combined into a calculated total for new emission standards by assessing the degree to which the different technologies will be deployed. As shown in Table 5.2.1-6, estimated costs for complying with the emission standards increase with increasing power ratings. We expect each of the listed technologies to apply to all the engines that need to meet the new emission standards. Estimated first-year cost impacts range from $300 to $1,300 for the different engine sizes, while long-term cost estimates range from $170 to $460.

Characterizing these estimated costs in the context of their fraction of the total purchase price and life-cycle operating costs is helpful in gauging the economic impact of the new standards. The estimated first-year cost increases for all engines are at most 2 percent of estimated engine prices, with even lower long-term effects, as described above.

Table 5.2.1-6: Diesel Engine Costs

	100 kW	400 kW	750 kW
Fuel injection upgrade	$95	$144	$264
Engine modifications	$72	$195	$697
Certification + PLT	$111	$129	$289
Total Engine Cost, year 1	$278	$468	$1,251
Total Engine Cost, year 6	$172	$221	$459

5.2.1.5 Marine Diesel Aggregate Costs

The above analyses developed incremental per-vessel cost recreational marine diesel engines. Using these per-engine costs and projections of future annual sales, we have estimated total aggregate annual costs for emission standards. The aggregate costs are presented on a cash-flow basis, with hardware and fixed costs incurred in the year the vehicle is sold. Table 5.2.1-7 presents a summary of this analysis. As shown in the table, aggregate net costs stay between $3 million and $6 million.

Table 5.2.1-7
Summary of Annual Aggregate Costs for Marine Diesel Engines (millions of dollars)

	2006	2010	2015	2020	2025
Total Costs	$6.2	$7.6	$2.8	$3.1	$3.4

To project annual sales, we started with the 1998 population estimates presented in Chapter 6. We then used the engine turnover rates and growth estimates to calculate annual sales. Table 5.2.1-8 provides a summary of the sales estimates used in the aggregate cost analysis.

Table 5.2.1-8
Estimated Annual Sales of Recreational Marine Diesel Engines

Engine Power Range (kW)	2000	2006	2010	2020
37 - 225	11,600	13,700	15,200	18,700
225 - 560	3,560	4,200	4,620	5,690
560 +	397	469	517	636

To calculate annual aggregate costs, the sales estimates have been multiplied by the per-unit costs discussed above. These calculations take into consideration vehicle sales and scrappage rates. The year-by-year results of the analysis are provided in Chapter 7.

5.2.2 Large Industrial Spark-Ignition Engines

We estimated the cost of upgrading LPG-fueled and gasoline-fueled Large SI engines. We developed the costs for individual technologies in cooperation with ICF, Incorporated and Arthur D. Little.[6] The analysis combines these individual figures into a total estimated cost for each type of engine, including markups to the retail level. A composite cost based on the mix of engine types provides an estimated industry-wide estimate of the per-engine cost impact.

Gasoline-fueled Large SI engines continue to rely on traditional carburetor designs rather than incorporating the automotive technology innovations introduced to address emission controls. Since natural gas- and LPG-fueled engines use comparable technologies, the analysis presents a single set of costs for both fuels.

The anticipated technology development is generally an outgrowth of automotive technologies. Over the last thirty years, engineers in the automotive industry have made great strides in developing new and improved approaches to achieve dramatic emission reductions with high-performing engines. In more recent years, companies have started to offer these same technologies for industrial applications. Fundamental to this technology development is the electronically controlled fuel system and catalytic converters.

Electronically controlled fuel systems allow manufacturers to more carefully meter fuel into the combustion chambers. This gives the design engineer an important tool to better control power and emission characteristics over the whole range of engine operation. Careful control of air-fuel ratio is also essential for effective catalyst conversion. The catalyst reduces the concentration of pollutant gases in the exhaust stream. We also consider development time to redesign the combustion chamber and intake air routing, as well as to combine the new control technologies and optimize engine calibrations. We include these efforts under the total R&D costs for each engine.

Gasoline engines can use either throttle-body or port-fuel injection. Manufacturers can likely reach the targeted emission levels using simpler throttle-body systems. However, the performance advantages and the extra assurance for full-life emission control from the more advanced port-fuel injection systems offer a compelling advantage. The analysis therefore projects that all gasoline engines will use port-fuel injection. The analysis does not take into account the performance advantages of port-fuel injection and therefore somewhat overestimates the cost impact of adopting new emission standards.

Gaseous-fuel engines have very different fuel metering systems due to the fact that LPG and natural gas evaporate readily at typical ambient temperatures and pressures. Manufacturers of these engines face a choice between continuing with conventional mixer technology and upgrading to injection systems. We are aware that manufacturers are researching gaseous injection systems, but we believe mixer technology will be sufficient to meet the standards. All the data supporting the feasibility of emission standards for LPG engines is based on engines using mixer technology.

5.2.2.1 Engine Technology

Tables 5.2.2-1 and 5.2.2-2 show the estimated costs of upgrading each of the engine types. The cost figures are in the form of retail-price equivalent for an individual engine. The tables include individual cost estimates of the various components involved in converting a baseline engine to comply with emission standards. The cost of the catalyst is based on a precious metal loading of 2.8 g/liter (primarily palladium, with small amounts of platinum and rhodium) and a catalyst volume 60 percent of total engine displacement.

The analysis incorporates a cost for potential warranty claims related to the new technologies by adding 5 percent of the increase in hardware costs. The industry has gained enough experience with electronic fuel systems that we expect a relatively low rate of warranty claims for them. Catalysts have been used for many years, but not in Large SI applications, so these technologies may cause a somewhat higher rate of warranty claims.

Even without EPA emission standards, manufacturers will conduct the research and development needed to meet the 2004 emission standards in California. The R&D impact of new EPA standards is therefore limited to the additional burden of complying with the 2007 requirements. Estimated costs for research and development are $175,000 for each engine family. This is based on about six months of time for an engineer and a technician on each fuel type for each engine family. We expect initial efforts to be more extensive, but cumulative learning should reduce per-family development costs for subsequent models. These fixed costs are increased by 7 percent to account for forward discounting, since manufacturers incur these costs before the new standards apply. Redesigning the first engine model will likely require significantly more time than this, but we expect the estimated level of R&D to be appropriate as an average level for the range of models in a manufacturer’s product line.

Table 5.2.2-2 presents separate costs for water-cooled and air-cooled gasoline engines. While many of the components are the same, the main differences include (1) a single fuel injector and simpler intake manifold for throttle-body injection, (2) smaller sales volume for amortizing fixed costs, and (3) substantial fixed costs for meeting the 2004 standards. Air-cooled engines are generally not certified already in California, largely because most applications involving air-cooled Large SI engines are preempted from California ARB's emission standards. To take this into account, we have added an estimate of $500,000 for R&D and $100,000 for tooling costs per engine family. Discounting these costs forward two years and amortizing over five years of sales results in an additional cost of $166 per air-cooled engine.

Table 5.2.2-1
Estimated Costs for an LPG-fueled Large SI Engine

	Baseline	Controlled
Hardware Cost to Manufacturer		
Regulator/throttle body	$50	$65
Intake manifold	$37	$37
Positive crankcase ventilation		$3
Fuel filter w/ lock-off system	$15	$15
LPG vaporizor	$75	$75
Governor	$40	$60
Converter temperature control valve		$15
Oxygen sensor		$19
ECM		$100
Wiring/related hardware		$42
Fuel system total	$217	$431
Catalyst/muffler		$229
Muffler	$45	$0
Total Hardware Cost	$262	$660
Markup @ 29%	$76	$191
Warranty markup @5%		$20
Total component costs	$338	$871
2004 Fixed costs		$0
2004 Incremental costs		$533
Fixed Cost to Manufacturer		
2007 R&D costs		$175,000
Units/yr.		2,000
Amortization period (7 % discounting)		5
2007 Fixed cost/unit	$0	$26
2007 Evap costs	$0	$0
2007 Incremental costs		$0

Table 5.2.2-2
Estimated Per-Engine Costs for Gasoline-Fueled Large SI Engines

	Water-cooled		Air-cooled	
	Baseline	Controlled	Baseline	Controlled
Hardware Cost to Manufacturer				
Carburetor	$51	$0	$51	$0
Injectors (each)		$17		$19
Number of injectors		4		1
Pressure Regulator		$11		$11
Fuel filter	$3	$4	$3	$4
Intake manifold	$35	$50	$35	$37
Positive crankcase ventilation		$3		$3
Fuel rail		$13		—
Throttle body/position sensor		$60		$76
Fuel pump	$15	$30	$15	$26
Oxygen sensor		$19		$19
ECM		$150		$140
Governor	$40	$60	$40	$60
Air intake temperature sensor		$5		$5
Manifold air pressure sensor		$11		$11
Injection timing sensor		$12		$12
Wiring/related hardware		$42		$42
Fuel system total	$144	$538	$144	$465
Catalyst/muffler		$229		$229
Muffler	$45		$45	
Total Hardware Cost	$189	$767	$189	$694
Markup @ 29%	$55	$222	$55	$201
Warranty markup @5%		$29		$25
Total Component Costs	$244	$1,018	$244	$920
2004 Fixed costs		$0		$600,000
2004 Fixed cost/unit		$0		$166
2004 Incremental costs		$775		$842
Fixed Cost to Manufacturer				
2007 R&D Costs		$175,000		$175,000
Units/yr.		1,750		1,000
Amortization period (7 % discounting)		5		5
2007 Fixed cost/unit		$30		$52
2007 Evap costs	$0	$13	$0	$13
2007 Incremental costs		$43		$65

In addition to these estimated costs for addressing exhaust emissions, we have analyzed the costs associated with reducing evaporative emissions from gasoline-fueled engines and vehicles. This effort consists of three primary areas—permeation, diurnal, and boiling.

To reduce permeation losses, we expect manufacturers to upgrade plastic or rubber fuel lines to use automotive-grade materials. These fuel lines are readily available at a cost premium of about $1 per linear foot. If an installed engine has an average of four feet of fuel line, this translates into an increased cost of $4 per engine.

The standard related to diurnal emissions can be met with a fuel cap that seals the fuel tank, relieving pressure as needed to prevent the tank from bursting or collapsing. The estimated cost of upgrading to such a fuel cap is conservatively set at $8, based on the aftermarket cost of comparable automotive fuel caps. Such caps would be expected to cost much less as an original equipment upgrade of an existing cap.

Many Large SI engines are installed in equipment in a way that poses little or no risk of fuel boiling during engine operation. A few models are configured in a way that causes this to be a possibility, at least under extreme conditions. Preventing fuel boiling is primarily a matter of isolating the fuel tank from heat sources, such as the engine compartment and the exhaust pipe. Some additional material may be needed to reduce heat exposure, such as a simple metal shield or a fiberglass panel. Given several years to redesign engines and equipment, we believe that manufacturers can readily incorporate such changes into their ongoing R&D programs. To account for several hours of engineering effort and a small amount of material, we estimate that these costs averaged over the whole set of gasoline-fueled engines will come to about $1 per engine.

5.2.2.2 Operating Cost Savings

Introducing electronic closed-loop fuel control will significantly improve engine operation, with corresponding cost savings, in three areas— reduced fuel consumption, less frequent oil changes and tuneups, and delayed time until rebuild.

It may also be appropriate to quantify the benefit of longer total engine lifetimes. For example, passenger cars with low-emission engine technologies last significantly longer than they did before manufacturers developed and applied these technologies. In addition, engine performance (responsiveness, reliability, engine warm-up, etc.) will also improve with the new technologies. However, these benefits are more difficult to quantify and the analysis therefore does not take them into account.

Fuel consumption rates will improve as manufacturers no longer design engines for operation in fuel-rich conditions. Some current systems already operate at somewhat leaner air-fuel ratios than in previous years, but even in these cases, engines generally revert to richer mixtures when accelerating. Closed-loop fuel systems generally operate close to stoichiometry, which improves the engine’s efficiency of converting the fuel energy into mechanical work. Information in the docket, including development testing, engineering projections, and user testimony, indicates an estimated 20-percent reduction in fuel consumption rates.[7,8,9] Table 5.2.2-3 shows the value of the estimated fuel savings. These values and calculations are generally based on our NONROAD emissions model. Since the NONROAD model does not account separately for air-cooled engines, calculated fuel savings are based on information we received during the comment period.

Table 5.2.2-3: Estimated Fuel Savings from Large SI Engines

	LPG	Natural gas	Gasoline–water-cooled	Gasoline–air-cooled
Horsepower	66	64	52	60
Load factor	0.39	0.49	0.58	0.58
Annual operating hours, hr/yr	1,368	1,164	534	1,000
Lifetime, yr	12	13	12	3
Baseline bsfc, lb/hp-hr	0.507	0.507	0.605	1.10
Improved bsfc, lb./hp-hr	0.406	0.406	0.484	0.88
Fuel density	4.2 lb./gal	0.05 g./ft^3	6.1 lb./gal	6.1 lb./gal
Fuel cost	$0.60/gal	$2.17/1000 ft^3	$1.10/gal	$1.10/gal
Annual fuel saved (gal/yr)	845	—	321	1,233
Annual fuel savings ($/yr)	$507	$160	$353	$1,357
Lifetime Fuel Savings (NPV)	$4,333	$1,427	$3,038	$3,810

In addition to the fuel savings, we expect Large SI engines to see significant improvements in reliability and durability. Open-loop fueling systems in uncontrolled engines are prone to drifting calibrations as a result of varying fuel quality, wear in engine components, changing ambient conditions, and other factors. Emission-control systems that operate with a feedback loop to compensate for changing conditions for a near-constant air-fuel ratio significantly reduces the following problems.

-incomplete (and eventually unstable) combustion
-absorption of fuel in lubricating oil
-deposits on valves, spark plugs, pistons, and other engine surfaces
-increased exhaust temperatures

Automotive engines clearly demonstrate that modern fuel systems reduce engine wear and the need for repairs.

This analysis incorporates multiple steps to take these anticipated improvements into account. First, oil change intervals are estimated to increase by 15 percent. Reduced fuel loading in the oil (and other improvements such as piston ring design) can significantly extend its working life. Similarly, tune-up intervals are estimated to increase by 15 percent. This results largely from avoiding an accumulation of deposits on key components, which allows for longer operation between regularly scheduled maintenance. Third, we estimate that engines will last 15 percent longer before needing overhaul. The reduced operating temperatures and generally reduced engine wear associated with closed-loop fuel systems account for this extended lifetime to rebuild. These quantitative estimates of maintenance-related savings are derived from observed changes in automotive performance when upgrading from carburetion to fuel injection. Table 5.2.2-4 summarizes the details of the methodology for converting these maintenance improvements into estimated cost savings over the lifetime of the engines.

Table 5.2.2-4: Maintenance

	LPG/ natural gas	Gasoline
Baseline oil change interval (hrs)	200	150
Improved oil change interval (hrs)	230	172.5
Cost per oil change ($)	$30	$30
Baseline tune-up interval (hrs)	400	400
Improved tune-up interval (hrs)	460	460
Cost per tune-up ($)	$75	$75
Baseline rebuild interval (hrs)	7,000	5,000
Improved rebuild interval (hrs)	8,050	5,750
Rebuild cost ($)	$800	$800
Baseline lifetime maintenance cost	$2,902	$2,573
Improved lifetime maintenance cost	$2,681	$2,354
Lifetime maintenance savings (NPV)	$221	$219

These large estimated fuel and maintenance savings relative to the estimated incremental cost of producing low-emitting engines raise the question of why normal market forces have failed to induce manufacturers to design and sell engines with emission-control technologies on the basis of the expected performance improvements. Since forklifts are the strongly dominant application using Large SI engines, this question effectively applies specifically to forklifts. We have observed that forklift users generally see their purchase as an expense that doesn't add value to a company's product, whether that applies to manufacturing, warehouse, or retail facilities. While operating expenses require less internal justification or decision-making, purchasing new equipment involves extensive review and oversight by managers who are very sensitive to capital expenditures. This is reinforced by an April 2000 article in a trade publication, which quotes an engineering estimate of 20- to 40-percent improvement in fuel economy while stating that it is unclear whether purchasers will tolerate any increase in the cost of the product.[10] Market theory would predict that purchasers select products with technologies that result in the lowest net cost (with some appropriate discount for costs incurred over time). It seems that companies have historically focused on initial costs to the exclusion of potential cost savings over time, which would account for the lack of emission-control technologies on current sales of Large SI engines.

This priority given to initial cost therefore affects the competitive decisions of engine manufacturers, who will be less willing to take the business risk of developing a more costly product than its competitors, even if the product would eventually provide substantial savings to the purchaser. Also, the initial costs of changing designs and using new technologies can serve as a deterrent to including newer cost-efficient technologies in established engine types.

In addition to the engine improvements described above, the costs associated with controlling evaporative emissions would be offset by savings from retaining more fuel that can be used to power the engine. To estimate these costs, we compare the total emission reductions from diurnal, running loss, hot soak, and refueling emissions with the total gasoline-fueled engine population in 2030. The resulting reduction of 0.04 tons hydrocarbon per engine translates into estimated annual savings of $11. Spread over 13 years and discounted to the point of sale leads to a net present value of $98 saved.

5.2.2.3 Compliance Costs

We estimate that certification costs come to $70,000 per engine family. We expect manufacturers to combine similar engines using different fuels in the same family. This expands the size of engine families, but calls for several tests to complete the certification process for each family. This includes six engine tests and $10,000 worth of engineering and clerical effort to prepare and submit the required information. Until engine designs are significantly changed, engine families can be recertified each year using carryover of the original test data. This cost is therefore amortized over five years of engine sales, with an assumed volume of 3,000 engines per year from each engine family. This engine-family sales volume is larger than those presented for amortizing fixed costs above, because engine families will include multiple fuel types. The resulting cost for certification is $6 per engine. Since these engines are currently not subject to any EPA emission requirements, the analysis includes a cost to recertify an upgraded engine model every five years. Since manufacturers already need to submit data for California certification, they will incur most of these costs independent of EPA requirements.

Manufacturers must generally do production-line testing on a quarterly basis, but reduced testing rates apply if engine testing shows consistently good test results. Manufacturers must generate and submit this test data to comply with the requirements adopted by California ARB. The EPA requirement for production-line testing therefore adds no test burden to manufacturers. Even with a transient duty cycle for certification, manufacturers may rely on steady-state test procedures at the production line. We therefore fully expect that manufacturers will need only to send the "California" test data to EPA to satisfy requirements for production-line testing. The analysis therefore includes no cost for additional routine testing of production engines. In fact, manufacturers may pursue alternate methods to show that production engines comply with emission standards, which may lead to lower testing costs.

We may select up to 25 percent of a manufacturers's engine families for in-use testing. This means that a manufacturer would need to have eight engine families for us to be able to select two engine families in a given year. Since this is likely to be a rare scenario, we project an annual testing rate of one engine family per year for each manufacturer to assess the cost of the in-use testing program. The analysis includes the cost of testing in-use engines on a dynamometer, which requires:

- engine removal and replacement ($4,000)
- transport ($1,000)
- steady-state and transient testing ($15,000)

Testing six engines and adding costs for administration and reporting of the testing program leads to a total cost of about $125,000 for an engine family. These costs can be spread over a manufacturer's total annual sales, which averages about 15,000 units for most companies. The resulting cost per engine is about $8.

As with production-line testing, we expect in-use emission testing to simultaneously satisfy California ARB and EPA requirements. In certain circumstances, however, we may use our discretion to direct a manufacturer to do in-use testing on an engine family separately from California ARB. Since we expect this to be the exception, this analysis likely overestimates the cost impact of adopting federal requirements to do in-use testing. In fact, manufacturers may reduce their compliance burden with the optional field-testing procedures. Table 5.2.2-5 shows the estimated costs from the various compliance programs.

In addition, we expect several manufacturers to upgrade testing facilities to allow for in-house measurement of emissions during transient engine operation. We generally expect each major manufacturer to equip one test cell with a new dynamometer and the associated controllers and analyzers. Installation of transient test cell would cost about $500,000. This consists of about $225,000 each for an electric dynamometer and the associated controllers, and $50,000 for a battery of sampling equipment and analyzers. An additional capital cost of $80 is estimated for precision calipers with digital readout to ensure dimensional accuracy of catalyst diameters. Dividing these costs over six engine families for five years leads to a calculated per-engine cost under $10.

Table 5.2.2-5
Cost of Compliance Programs

Compliance Program Element	Estimated Per-Engine Costs
Certification	$6
In-use testing	$8
Facility upgrade	$7
Total	$21

5.2.2.4 Total Costs

Table 5.2.2-6 presents the combined cost figures for the different engine types and calculates a composite cost based on their estimated distribution. The estimated 2004 costs are based on the adding component costs and compliance costs. No R&D cost is estimated for manufacturers to do additional development work beyond what is necessary to comply with California ARB standards. Conversely, the estimated 2007 costs are based on R&D (and ongoing compliance costs), with no anticipated increase in component costs, except those related to reducing evaporative emissions. The estimated cost of complying with the emission standards is sizable, but the lifetime savings from reduced operating costs nevertheless more than compensate for the increased costs. Costs for gasoline engines are presented as a composite of air-cooled models (estimated 3 percent of total sales) and water-cooled models (estimated 20 percent of total sales).

Table 5.2.2-6
Estimated First-Year Cost Impacts of New Emission Standards

Standards	Engine Type	Sales Mix of Engine Types	Increased Production Cost per Engine*	Lifetime Operating Costs per Engine (NPV)
2004	LPG	68%	$550	$-4,330
	natural gas	9%	$550	$-1,650
	gasoline	23%	$800	$-3,140
	Composite	—	$605	$-3,815
2007	LPG	68%	$40	—
	natural gas	9%	$40	—
	gasoline	23%	$60	$-100
	Composite	—	$50	$-20

*The estimated long-term costs decrease by about 35 percent.

5.2.2.5 Large SI Aggregate Costs

The above analyses developed incremental per-vessel cost estimates for Large SI engines. Using these per-engine costs and projections of future annual sales, we have estimated total aggregate annual costs for the exhaust and evaporative emission standards. The aggregate costs are presented on a cash-flow basis, with hardware and fixed costs incurred in the year the vehicle is sold and fuel savings occurring as the engines are operated over their lifetimes. Table 5.2.2-7 presents a summary of this analysis. As shown in the table, aggregate costs generally range from $70 million to $90 million. Net costs decline as fuel savings continue to ramp-up as more vehicles meeting the standards are sold and used. Fuel savings are projected to more than offset the costs of the program starting by the second year of the program.

Table 5.2.2-7: Summary of Annual Aggregate Costs and Fuel Savings for Large SI Engines (millions of dollars)

	2004	2005	2010	2015	2020
Total Costs	$89	$91	$71	$73	$81
Fuel Savings	($53)	($103)	($326)	($421)	($472)
Net Costs	$36	($12)	($255)	($348)	($391)

To project annual sales, we started with the number of model year 2000 engines estimated by the NONROAD model for the 2000 calendar year. We then applied a growth rate of 3 percent of year 2000 sales (increasing by 3,900 units annually) to estimate future sales. Table 5.2.2-8 provides a summary of the sales estimates used in the aggregate cost analysis.

Table 5.2.2-8
Estimated Annual Sales of Large SI Engines

2000	2004	2010	2020
130,000	145,600	169,000	208,000

To calculate annual aggregate costs, the sales estimates have been multiplied by the per-unit costs. Annual fuel savings have been calculated based on the reduction in fuel consumption expected from the standards (as described in section 5.2.2.2 of this chapter) as calculated by the NONROAD model. The model takes into consideration vehicle sales and scrappage rates. The year-by-year results of the analysis are provided in Chapter 7.

5.2.3 Recreational Vehicles

5.2.3.1 Technologies and Estimated Costs

We estimated costs separately for snowmobiles, ATVs, and off-highway motorcycles. Individual technology costs were developed in cooperation with EPA by ICF Incorporated and Arthur D. Little - Acurex Environmental.[11] Any comments received on the rule were also evaluated and included where appropriate. Costs were prepared for a typical engine that falls within the displacement ranges noted below. Costing out multiple engine sizes allowed us to estimate significant differences in costs for smaller vs. larger engines. The costs include a mark-up to the retail level. This Chapter also provides a brief overview of the technologies, with more information provided in Chapter 4. Costs are provided for both the baseline technology and the new technology (e.g., a two-stroke engine and a four-stroke engine), with the cost of the change in technology due to the new standards being the increment between the two costs.

The R&D costs shown are average costs. The first engine line R&D cost is expected to be significantly higher but the costs would be distributed across the manufacturer's entire product line.[12] To account for any additional warranty cost associated with a change in technology, we have added 5 percent of the incremental hardware cost.[13]

As noted in section 5.1, fixed costs are spread over the first five years of sales for purposed of the cost analysis, with the exception of new facility costs for ATV testing which are spread over 10 years. We have used 10 years for amortization rather than 5 years because we believe it is more representative for a capital investment that will be used for at least that long a time period. We estimated that R&D and facility costs will be incurred three years prior to production on average and tooling and certification costs will be incurred one year prior to production. These fixed costs were then increased seven percent for each year prior to the start of production to reflect the time value on money.

To approximate average annual sales per engine line, we divided the total 2001 annual unit sales by estimated total number of engines lines industry-wide.[2] Based on limited sales data from individual manufacturers provided to EPA on a confidential basis, there appears to be a large distinction in sales volume between small engine and large engine displacements for ATVs. The cost analysis accounts for this difference by using a larger annual sales rate per engine line for larger displacement ATVs, as shown below.

As noted below, the fuel savings over the life of the vehicle due to some of the projected technology changes can be substantial and for snowmobiles are projected to offset the cost of the emission controls. As discussed below, these fuel savings will occur because 2-stroke powerplants are inefficient and the changes needed to reduce hydrocarbons from these engines also improve fuel consumption. Because the fuel savings outweigh up front costs, one might question why manufacturers have continued to use 2-stroke engines. Manufacturers have not made these changes in the absence of emission standards for several likely reasons. Since fuel costs are not a significant portion of the overall price of ownership, customers may not place a high value on fuel economy compared to initial cost and engine simplicity. Especially in the case of snowmobiles and off-road motorcycles, manufacturers have built a customer base over many years using 2-stroke technology; ATVs which are dominantly 4-stroke are relatively new to the recreational vehicle market.. The engines are relatively simple and the production costs are relatively low because the manufacturers have been building the engines for many years. To capture the fuel economy benefits, manufacturers would have to invest substantially in R&D and more complex powerplants in the face of uncertainty with regard to market acceptance of the new product. Such a move could also lower profits per vehicle. Considering all these factors, manufacturers have historically chosen to focus improvements in other areas such as increasing horsepower and overall vehicle design.

However, manufacturers are now introducing 4-strokes and direct injection 2-stroke engines into the snowmobile market. For model year 2003, all manufacturers will have at least one 4-stroke snowmobile model available and one manufacturer is introducing direct injection 2-stroke technology. This may mean that manufacturers are adjusting their perspectives on potential marketplace acceptance of advanced technologies.

5.2.3.1.1 Snowmobiles

Phase 1

Snowmobiles are currently almost exclusively powered by carbureted 2-stroke engines. However, as noted above, manufacturers are beginning to introduce 4-strokes and 2-stroke direct fuel injection. Manufacturers have also provided comment that they plan to rely more heavily on these technologies to meet Phase 1 standards than originally thought prior to proposal. For these reasons, we have adjusted our projected baseline technology mix as well as our projected

---

[2] Based on publicly available product information for the large manufacturers, we estimated 32 engine lines for snowmobiles, 43 lines for ATVs, and 42 lines for off-highway motorcycles for the 2001 model year.

technology mix for the Phase 1 standards for purposes of the cost analysis. Based on discussions with manufacturers, we believe that up to 10 percent of production will be 4-stroke and 10 percent will be direct fuel injection for Phase 1. We believe manufacturers will be ramping up the introduction of these technologies in order to obtain experience with them prior to the start of the program. These technologies will provide surplus emissions reductions which will allow the manufacturers to use lesser technologies on other models under the averaging program.

For cost purposes, we are projecting that 4-stroke engines are likely to be equipped with electronic fuel injection systems to optimize emissions and overall performance of these engines. Therefore we are including electronic fuel injection costs for 4-strokes. Tables 5.2.3-1 through 5.2.3-4 provide costs for direct injection systems (both air assisted direct injection and pump assisted direct injection) and for converting from a 2-stroke to 4-stroke engine with electronic fuel injection.

We have estimated the incremental cost of going from carbureted 2-stroke to direct injection to range from $262 to $342 per engine and conversion to 4-stroke to be about $454 to $770. Electronic fuel injection for snowmobiles is estimated to incrementally cost $174 to $119. Note that the overall consumer costs for these advanced technologies are substantially lower after the fuel economy improvements are taken into account. Estimates of the fuel savings are provided below. For 4-stroke snowmobiles, where possible, we have examined available price information on manufacturer web sites for the various 4-stroke models and comparable 2-stroke models and found price differences to be similar to our cost estimates in most cases. We did not receive detailed public comments on our cost estimates for the various snowmobile technologies.

Table 5.2.3-1: Air Assisted Direct Injection System Costs for Snowmobiles

	< 500 cc		> 500cc	
	Baseline	Modified	Baseline	Modified
Hardware Costs				
Carburetor	$60		$60	
Number Required	2		3	
Fuel Metering Solenoid (each)		$15		$15
Number Required		2		3
Air Pump		$25		$25
Air Pump Gear		$5		$5
Air Pressure Regulator		$5		$5
Throttle Body/Position Sensor		$35		$35
Intake Manifold		$30		$30
Electric Fuel Pump	$5	$5	$5	$5
Fuel Pressure Regulator		$3		$3
ECM		$140		$140
Air Intake Temperature Sensor		$5		$5
Manifold Air Pressure Sensor		$11		$11
Injection Timing Sensor/Timing Wheel		$10		$10
Wiring/Related Hardware		$20		$20
Hardware Cost to Manufacturer	$125	$324	$185	$339
Labor @ $28 per hour	$1	$14	$2	$21
Labor overhead @ 40%	$1	$6	$1	$8
OEM mark-up @ 29%	$37	$100	$55	$107
Royalty @ 3%		$10		$10
Warranty Mark-up @ 5%		$10		$8
Total Component Costs	**$164**	**$464**	**$243**	**$493**
Fixed Cost to Manufacturer				
R&D Costs	$0	$178,500	$0	$178,500
Tooling Costs	$0	$25,000	$0	$25,000
Units/yr.	4,400	4,400	4,400	4,400
Years to recover	5	5	5	5
Fixed cost/unit	**$0**	**$13**	**$0**	**$13**
Total Costs	**$164**	**$476**	**$243**	**$505**
Incremental Total Cost		**$312**		**$263**

Table 5.2.3-2: Pump-Assisted Direct Fuel Injection System Costs for Snowmobiles

	< 500cc		> 500cc	
	Baseline	**Modified**	**Baseline**	**Modified**
Hardware Costs				
Carburetor	$60		$60	
Number Required	2		3	
Nozzle/Accumulator (each)		$33		$33
Number Required		2		3
High-Pressure Cam Fuel Pump		$20		$25
Cam Pump Gear		$5		$5
Throttle Body/Position Sensor		$35		$35
Intake Manifold		$30		$30
Fuel Transfer Pump	$5	$5	$5	$5
ECM		$140		$140
Air Intake Temperature Sensor		$5		$5
Manifold Air Pressure Sensor		$11		$11
Injection Timing Sensor/Timing Wheel		$10		$10
Wiring/Related Hardware		$20		$20
Hardware Cost to Manufacturer	$125	$347	$185	$385
Labor @ $28 per hour	$1	$14	$2	$21
Labor overhead @ 40%	$1	$6	$1	$8
OEM mark-up @ 29%	$37	$106	$55	$120
Royalty @ 3%		$10		$12
Warranty Mark-up @ 5%		$11		$10
Total Component Costs	**$164**	**$494**	**$243**	**$556**
Fixed Cost to Manufacturer				
R&D Costs	$0	$178,500	$0	$178,500
Tooling Costs	$0	$25,000	$0	$25,000
Units/yr.	4,400	4,400	4,400	4,400
Years to recover	5	5	5	5
Fixed cost/unit	**$0**	**$13**	**$0**	**$13**
Total Costs	**$164**	**$506**	**$243**	**$568**
Incremental Total Cost		**$343**		**$327**

Table 5.2.3-3: Two-Stroke to Four Stroke Conversion Costs for Snowmobiles

	< 500 cc		> 500 cc	
	2-Stroke	**4-Stroke**	**2-Stroke**	**4-Stroke**
Engine	$400	$700	$650	$1,170
Clutch	$50	$75	$80	$120
Labor @ $28 per hour	$14	$21	$14	$21
Labor overhead @ 40%	$6	$8	$6	$8
Markup @ 29%	$136	$233	$217	$383
Warranty Mark up @ 5%		$16		$28
Total Component Costs	**$606**	**$1,053**	**$967**	**$1,730**
Fixed Cost to Manufacturer				
R&D Costs	$0	$94,416	$0	$94,416
Tooling Costs	$0	$20,000	$0	$20,000
Units/yr.	4,400	4,400	4,400	4,400
Years to recover	5	5	5	5
Fixed cost/unit	**$0**	**$7**	**$0**	**$7**
Total Costs	**$606**	**$1,060**	**$967**	**$1,737**
Incremental Total Cost		**$455**		**$770**

Table 5.2.3-4: Electronic Fuel Injection Costs for Snowmobiles

Fuel Injection Costs	400cc		700cc	
	Baseline	Modified	Baseline	Modified
Hardware Costs				
Carburetor	$60		$60	
Number Required	2		3	
Injectors (each)		$12		$12
Number Required		2		3
Pressure Regulator		$10		$10
Intake Manifold		$30		$35
Throttle Body/Position Sensor		$35		$35
Fuel Pump	$5	$20	$5	$20
ECM		$100		$100
Air Intake Temperature Sensor		$5		$5
Manifold Air Pressure Sensor		$10		$10
Injection Timing Sensor		$5		$5
Wiring/Related Hardware		$10		$10
Hardware Cost to Manufacturer	**$125**	**$249**	**$185**	**$266**
Labor @ $28 per hour	$1	$4	$2	$6
Labor Overhead @ 40%	$1	$2	$1	$3
Manufacturer Mark-up @ 29%	$37	$72	$54	$77
Warranty Mark-up[a] @ 5%		$6		$4
Total Component Costs	**$164**	**$333**	**$242**	**$356**
Fixed Cost to Manufacturer				
R&D Costs	$0	$69,417	$0	$69,417
Tooling Costs	$0	$10,000	$0	$10,000
Units/yr.	4,400	4,400	4,400	4,400
Years to recover	5	5	5	5
Fixed cost/unit	**$0**	**$5**	**$0**	**$5**
Total Costs ($)	**$164**	**$338**	**$242**	**$361**
Incremental Total Cost ($)		**$175**		**$119**

In addition to the advanced technologies, we are also basing the cost analysis for Phase 1 standards on some use of engine modifications, carburetor improvements, and recalibration. We are projecting lower usage of this approach compared to the proposal (60% compared to 100%) based on the comments we received concerning the use of advanced technology to meet Phase 1 standards. Manufacturers are likely to be able to reduce emissions for some models by leaning out the air/fuel mixture, improving carburetors for better fuel control and less production variation, and modifying the engine to withstand higher temperatures and potential misfire episodes attributed to enleanment. Engine modifications are also likely to be made to improve air/fuel mixing and combustion. The cost estimates for engine modifications and carburetor improvements are provided in Tables 5.2.3-5 and 5.2.3-6. Recalibration work is included as part of the R&D for the technologies. The incremental cost per unit for engine modifications is estimated to be $18 to $25, with modifications to the carburetor estimated to cost an additional $18 to $24 per engine.

Table 5.2.3-5: Snowmobile Engine Modification Costs for Two-Stroke Engines

	< 500 cc		> 500 cc	
	Baseline	Modified	Baseline	Modified
Hardware Costs				
Improved Pistons	$10	$12	$12	$15
Number Required	2	2	3	3
Hardware Cost to Manufacturer	$20	$24	$36	$45
Labor @ $28 per hour	$6	$6	$8	$8
Labor Overhead @ 40%	$2	$2	$3	$3
Manufacturer Mark-up @ 29%	$6	$7	$10	$13
Warranty Mark-up @ 5%		$0		$0
Total Component Costs	$34	$39	$57	$69
Fixed Cost to Manufacturer				
R&D Costs per line	$0	$178,500	$0	$178,500
Tooling Costs	$0	$25,000	$0	$25,000
Units/yr.	4,400	4,400	4,400	4,400
Years to recover	5	5	5	5
Fixed cost/unit	$0	$13	$0	$13
Total Costs	$34	$51	$57	$81
Incremental Total Cost		$18		$25

Table 5.2.3-6: Modified Carburetor Costs for Snowmobiles

	< 500 cc		**> 500 cc**	
	Baseline	Modified	Baseline	Modified
Hardware Costs				
Carburetor	$60	$65	$60	$65
Number Required	2	2	3	3
Hardware Cost to Manufacturer	$120	$130	$180	$195
Labor @ $28 per hour	$1	$1	$2	$2
Labor Overhead @ 40%	$1	$1	$1	$1
Manufacturer Mark-up @ 29%	$35	$38	$53	$57
Warranty Mark-up @ 5%		$1		$1
Total Component Costs	**$157**	**$171**	**$236**	**$256**
Fixed Cost to Manufacturer				
R&D Costs per line	$0	$61,875	$0	$61,875
Tooling Costs	$0	$5,000	$0	$5,000
Units/yr.	4,400	4,400	4,400	4,400
Years to recover	5	5	5	5
Fixed cost/unit	**$0**	**$4**	**$0**	**$4**
Total Costs	**$157**	**$175**	**$236**	**$260**
Incremental Total Cost		**$18**		**$24**

Phase 2 and Phase 3

We have based the cost analysis for the Phase 2 and Phase 3 standards primarily on the expanded use of direct fuel injection 2-stroke engines and 4-stroke engines. We expect that by the 2010 time frame these two technologies will be fully developed and able to be used on a larger fraction of the fleet. Our projections that these later Phases will be met primarily through the expanded use of these technologies is consistent with our discussions with manufacturers. This chapter provides a cost analysis for the primary Phase 2 program which calls for a 50 percent reduction from baseline levels for both HC and a 30 percent reduction for CO emissions in 2010. The Phase 3 standard begins in 2012 and requires a further reduction in CO from 30 percent to 50 percent. Manufacturers have some flexibility in meeting the Phase 3 standards which allows them to meet less stringent CO requirements if additional HC reductions are achieved. We would expect the same technologies to be used to meet these all of these programs but in somewhat different combinations. For example, some manufacturers may rely on 4-stroke technology more so than direct injection 2-stroke technology. This is discussed in detail in Chapter 4. With averaging, manufacturers, will optimize their technology paths for each phase of standards and each manufacturer will have somewhat different mixes of technology.

For Phase 2 and Phase 3, we are projecting that 50 and 70 percent of models, respectively, will be equipped with either direct injection 2-stroke or 4-stroke engines. We anticipate that remaining models will consist of 2-stroke technologies with some further optimization. One additional technology that may be used is pulse air. We are projecting the use of pulse air systems with recalibration on a portion of the snowmobile engines that are not equipped with advanced technology systems. Pulse air provides a small incremental emission reduction for these engines and would help manufacturers meet the Phase 2 and Phase 3 average HC and CO standards. As shown in Table 5.2.3-7, we have estimated pulse air to cost about $40. Catalysts are also a potential option for snowmobiles but would entail a significant R&D effort and may not be available for snowmobile applications in the 2010 time frame. However, we believe manufacturers are more likely to focus on developing the advanced technologies noted above, which provide the consumer with benefits in addition to lower emissions. Therefore, we have not included catalyst costs in our cost estimates.

Table 5.2.3-7: Calibration/Pulse-Air Costs for Snowmobiles

	Baseline	Modified
Hardware Costs		
Pulse Air Valve		$18
Labor @ $28 per hour		$1
Labor overhead @ 40%		$0
Markup @ 29%		$5
Warranty Mark up @ 5%		$0
Total Component Costs	**$0**	**$25**
Fixed Cost to Manufacturer		
R&D Costs		$54,750
Tooling Costs		$200,000
Units/yr.		4,400
Years to recover		5
Fixed cost/unit		**$15**
Total Costs	**$0**	**$40**
Incremental Total Cost		**$40**

5.2.3.1.2 All-terrain Vehicles (ATVs)

ATVs are equipped primarily with carbureted 4-strokes, with 2-stroke engines used mostly in small displacement and sport models. We expect manufacturers to take several steps in response to the standards and test cycle requirements. Beginning in 2006, we expect most manufacturers will take some advantage of the transitional interim test procedures and standards offered from 2006-2008 but will need to phase out the use of 2-stroke engines. In addition, for the 4-stroke ATVs, we are also projecting that as manufacturers transition to the chassis test cycle, recalibration will be needed and that pulse air systems will be used on about 50 percent of the models to ensure that the fleet meets the standards on average. Pulse air systems are currently used on a few ATV and off-highway motorcycles models to meet California standards. We do not believe that the level of the standards will require the use of pulse air beyond 50 percent, given that only a few models in California are currently equipped with the technology. Using pulse air may give the manufacturer more flexibility in calibrating for performance on some models. Technological feasibility is discussed in Chapter 4.

We are basing our technology projection on what manufacturers have done to meet the California emissions standards. We believe this to be the most likely technology path for manufacturers, because 4-strokes are accepted in the market and provide consumers with fuel economy and reliability benefits. Beyond using 4-stroke engines, we expect manufacturers to undertake an R&D effort to recalibrate models and select and optimize pulse air systems. Some recalibration is likely, due to the change in test procedures. We received comments that we underestimated the amount of R&D necessary for ATVs and, upon evaluation, have adjusted the estimates upwards. We continue to believe manufacturers will approach this effort in an orderly manner and we would expect them to focus R&D on a first engine line and then apply what they learn to subsequent lines.[3] Table 5.2.3-8 provides the estimated R&D for ATVs. We believe the increased level of R&D shown below is substantial considering the technological difficulty of the final standards. We believe the estimated amounts also are sufficient because manufacturers have already invested in R&D and technology to meet the California program which contains standards that are similar in stringency.

Table 5.2.3-8: R&D Cost Estimate for ATVs

	< 200 cc	> 200 cc
Base R&D Costs for 1st engine line	$724,000	$724,000
Engine lines per manufacturer	8	8
Base R&D per line	$90,500	$90,500
Individual Engine Line R&D	$238,000	$238,000
Total R&D per line	328,500	$328,500
Units/yr.	5,600	20,000
Years to recover	5	5
R&D Fixed cost/unit	**$16.40**	**$4.59**

Tables 5.2.3-9 and 5.2.3-10 provide cost estimates for the ATV technologies discussed above. We estimate the incremental cost per unit of replacing a 2-stroke engine with a 4-stroke engine to be about $219 to $349, depending on engine size. Costs for a mechanical pulse air system is estimated to be about $27 to $33 per unit. As shown in the tables below, fixed costs for larger displacement models are spread over a significantly larger annual unit sales volume to account for the relatively high average number of unit sales per engine line for these products.

[3] We have estimated a base R&D effort of 12 months for the first engine line and 6 additional months for subsequent lines and have used the costing methodology provided in the Arthur D. Little - Acurex cost report to calculate the increased R&D cost.

Table 5.2.3-9: Two-Stroke to Four Stroke Conversion Costs for ATVs

	< 200 cc		> 200 cc	
	2-Stroke	**4-Stroke**	**2-Stroke**	**4 Stroke**
Hardware Costs				
Engine	$400	$550	$500	$750
Labor @ $28 per hour	$14	$21	$14	$21
Labor overhead @ 40%	$6	$8	$6	$8
Markup @ 29%	$122	$168	$151	$226
Warranty Mark up @ 5%		$8		$13
Total Component Costs	**$542**	**$755**	**$671**	**$1,018**
Fixed Cost to Manufacturer				
R&D Costs	$0	$94,416	$0	$94,416
Tooling Costs	$0	$15,000	$0	$18,000
Units/yr.	5,6200	5,600	20,000	20,000
Years to recover	5	5	5	5
Fixed cost/unit	**$0**	**$5**	**$0**	**$2**
Total Costs	**$541**	**$760**	**$670**	**$1,019**
Incremental Total Cost		**$219**		**$349**

Table 5.2.3-10: Pulse-Air Costs for Four-Stroke ATVs

	≤ 200 cc		> 200 cc	
	Baseline	**Modified**	**Baseline**	**Modified**
Hardware Costs				
Pulse Air Valve		$18		$18
Labor @ $28 per hour		$1		$1
Labor overhead @ 40%		$0		$0
Markup @ 29%		$5		$5
Warranty Mark up @ 5%		$0		$0
Total Component Costs	**$0**	**$25**	**$0**	**$25**
Fixed Cost to Manufacturer				
Tooling Costs		$159,091		$159,091
Units/yr.		5,600		20,000
Years to recover		5		5
Fixed cost/unit		**$7**		**$2**
Total Costs	**$0**	**$33**	**$0**	**$27**
Incremental Total Cost		**$33**		**$27**

5.2.3.1.3 Off-highway Motorcycles

Currently, off-highway motorcycles are about 65 percent 2-stroke, with many of the 2-stroke engines used in competition and youth models. As with ATVs, we expect that manufacturers will meet standards primarily by using 4-stroke engines. Manufacturers may also use pulse air systems and recalibration on a relatively small fraction of their models to ensure their overall fleet meets the standards. We have estimated their use for off-highway motorcycles at about 25 percent for purposes of the cost analysis. The R&D efforts will likely be lower for off-highway motorcycles than for ATVs because the level of the standard is less stringent and there is no change in the test procedure from what is now required in California. We do not believe the standards will require pulse air technology in more than 25 percent of models, given that only a few models in California are currently equipped with this technology. As discussed in 5.2.3.4 below, vehicles used solely for competition are exempt from standards and we expect some 2-stroke competition models to remain in the market.

Tables 5.2.3-11 and 5.2.3-12 provide cost estimates for off-highway motorcycle technologies for three engine displacement ranges. We estimate the incremental cost per unit of replacing a 2-stroke engine with a 4-stroke engine to be about $219 to $353, depending on engine size. Costs for a mechanical pulse air valve system and recalibration is estimated to be about $39 per unit.

Table 5.2.3-11: Two-Stroke to Four Stroke Conversion Costs for Off-highway Motorcycles

	< 125 cc		125cc < 250 cc		> 250cc	
	2-Stroke	**4-Stroke**	**2-Stroke**	**4-Stroke**	**2-Stroke**	**4-Stroke**
Hardware Costs						
Engine	$400	$550	$450	$650	$500	$750
Labor @ $28 per hour	$14	$21	$14	$21	$14	$21
Labor overhead @ 40%	$6	$8	$6	$8	$6	$8
Markup @ 29%	$122	$168	$136	$197	$151	$226
Warranty Mark up @ 5%		$8		$10		$13
Total Component Costs	**$542**	**$755**	**$606**	**$886**	**$671**	**$1,018**
Fixed Cost to Manufacturer						
R&D Costs	$0	$94,416	$0	$94,416	$0	$94,416
Tooling Costs	$0	$15,000	$0	$15,000	$0	$15,000
Units/yr.	6,000	6,000	6,000	6,000	6,000	6,000
Years to recover	5	5	5	5	5	5
Fixed cost/unit	**$0**	**$5**	**$0**	**$5**	**$0**	**$5**
Total Costs	**$542**	**$760**	**$606**	**$891**	**$670**	**$1,023**
Incremental Total Cost		**$219**		**$286**		**$353**

Table 5.2.3-12: Four-stroke Calibration/Pulse-Air Costs for Off-highway Motorcycles

	< 125 cc		125 < 250 cc		≥ 250cc	
	Baseline	**Modified**	**Baseline**	**Modified**	**Baseline**	**Modified**
Hardware Costs						
Pulse Air Valve		$18		$18		$18
Labor @ $28 per hour		$1		$1		$1
Labor overhead @ 40%		$0		$0		$0
Markup @ 29%		$5		$5		$5
Warranty Mark up @ 5%		$1		$1		$1
Total Component Costs	**$0**	**$25**	**$0**	**$25**	**$0**	**$25**
Fixed Cost to Manufacturer						
R&D Costs		$54,750		$54,750		$54,750
Tooling Costs		$250,000		$250,000		$250,000
Units/yr.		6,000		6,000		6,000
Years to recover		5		5		5
Fixed cost/unit		**$14**		**$14**		**$14**
Total Costs ($)	**$0**	**$39**	**$0**	**$39**	**$0**	**$39**
Incremental Total Cost ($)		**$39**		**$39**		**$39**

5.2.3.1.4   Crankcase Controls

The proposal included a requirement for crankcase emission controls for recreational vehicles. Crankcase controls have been required on passenger cars for more than 30 years, and it is normally a simple process of routing crankcase exhaust emissions to the engine intake to be burned as part of normal engine operation. Most current 4-stroke recreational vehicle engines use positive crankcase ventilation systems today; crankcase emissions are not significant in current 2-stroke engines. For those converting to 4-stroke in the future, crankcase controls will be required at a cost of about $3 per engine. These are included in the 2-stroke to 4-stroke conversion and replacement costs.

5.2.3.1.5 Permeation Control from Recreational Vehicles

As discussed in earlier chapters, we believe that there are several technologies that could be used to meet the permeation emission standards. Table 5.2.3-13 presents our best estimates of the costs of applying various evaporative emission control technologies to recreational vehicles using the average fuel tank sizes and hose lengths discussed in Chapter 6.

The cost for including low permeation barrier platelets in blow-molded fuel tanks (generally known as Selar®) is based on increased material costs. No changes should be necessary to the blow-molding equipment. We used 10 percent EVOH which is about $3 per pound and 90 percent HDPE which is about $0.50 per pound. This equates to a price increase of about $0.30 per pound. Depending on the shape of the fuel tank and the wall thickness, recreational vehicle fuel tanks weigh about 1-1.3 pounds per gallon of capacity. Costs for multi-layer fuel tanks with continuous barriers are not included, but would be expected to be higher because two additional injection screws would be necessary for the barrier and adhesion layers. Another option would be to mold the entire fuel tank of a low permeation material such as nylon, an acetal copolymer, or a thermoplastic polyester. These materials have list prices of about $2.00 per pound; therefore, the cost of using these alternative materials would be about 7 times higher than presented below for barrier platelets with 10% EVOH.

Surface treatment costs are based on price quotes from a companies that specialize in this fluorination[14] and sulfonation.[15] The fluorination costs are a function of the geometry of the fuel tanks because they are based on how many fuel tanks can be fit in a treatment chamber. The price sheet referenced for our fluorination prices assumes rectangular shaped containers. For irregular shaped fuel tanks, the costs would be higher because they would have to be fit into baskets with volumes larger than the volume of the fuel tanks. Therefore, we consider a void space equal to about 25 percent of the volume of the fuel tank. For sulfonation, the shape of the fuel tanks is less of an issue because the treatment process is limited only by the spacing on the production line which is roughly the same for the range of fuel tank sizes used in recreational vehicles. These prices do not include the cost of transporting the tanks; we estimated that shipping, handling and overhead costs would be an additional $0.22 to $0.81 per fuel tank depending on tank size.[16]

Barrier fuel hose incremental costs estimates are based on costs of existing products used in marine and automotive applications.[17,18,19] We estimate that the cost increment compared to R7 hose used in most recreational applications today is about $0.60 per foot. Some manufacturers have commented that they do not use hose clamps today, but would need them if they use barrier hose. Other manufacturers already use hose clamps, but may need to upgrade them in some applications. To be conservative, we consider the cost of adding hose clamps to all applications. These hose clamps cost about $0.20 each.[20] For ATVs and OHMCs, we include the costs of two hose clamps for each vehicle (one for each end of the hose). Snowmobiles can require 4 to 8 hose clamps depending on the fuel pump configuration, number of carburetors, and if a fuel return line is included. We include the cost of 6 hose clamps for snowmobiles in this analysis.

Table 5.2.3-13: Permeation Control Technologies and Incremental Costs

Technology		*Snowmobiles* *11 gallon tank* *3.5 ft. hose*	*ATVs*** *4 gallon tank* *1 ft. hose*	*OHMCs* *3 gallon tank* *1.5 ft. hose*
barrier platelets (10% EVOH)		$3.30	$1.50	$1.20
sulfonation	treatment*	$1.50	$1.20	$1.20
	shipping/handling	$0.81	$0.30	$0.22
fluorination	treatment*	$8.39	$3.23	$2.42
	shipping/handling	$0.81	$0.30	$0.22
1/4" I.D. hose	barrier fuel hose*	$2.71	$0.77	$1.16
	hose clamps*	$1.55	$0.52	$0.52

* includes a 29% markup for overhead and profit
** includes utility vehicles

Manufacturers, with high enough production volumes, could reduce the costs of sulfonating fuel tanks by constructing an in-house treatment facility. The cost of a sulfonation production line facility that could treat 150-500 thousand fuel tanks per year would be approximately $800,000.[21] This facility, which is designed to last at least 10 years, is made up of a SO_3 generator, a scrubber to clean up used gas, a conveyor belt, and injection systems for the SO_3 gas and for the neutralizing agent (ammonia solution). The manufacturer of this equipment estimates that the operating costs, which includes electricity and chemicals, would be about 3 cents per tank. Based on a production capacity of 150,000 units per year, and a 10 year life, the average sulfonation cost per fuel tank would be about $0.60. These costs would be lower for higher production volumes. In addition, if a manufacturer were to sulfonate their fuel tanks in-house, they would not need to pay shipping and handling costs.

To determine the total costs per recreational vehicle we use the scenario that all manufacturers use sulfonation to reduce permeation from their fuel tanks and use barrier fuel hose. For this analysis, we consider the cost of shipping fuel tanks to an outside vendor for treatment rather than using the lower cost of in-house sulfonation. For competition off-highway motorcycles, which make up about 29 percent of OHMC sales, we assume that no low permeation technology would be used. We estimate the total per vehicle costs to be $6.56 for snowmobiles, $2.79 for ATVs, and $3.10 for non-competition OHMCs. Weighting a cost of $0 for competition OHMCs, we get an average cost of $2.14 per off-highway motorcycle. These costs do not include the fuel savings associated with a reduction permeation which is discussed below in section 5.2.3.2.3.

As a sensitivity analysis, we estimated what the costs would be if the fuel tank permeation control technology applied by manufacturers were equally distributed by barrier platelets, sulfonation, and fluorination. Not considering fuel costs, the estimated fuel tank costs, under this scenario, would be $4.93 for snowmobiles, $2.18 for ATVs, and $1.75 for non-competition OHMCs. This represents about a 20-100% increase in the cost estimates for fuel tanks (no change in fuel hose costs). However, we believe that manufacturers are likely to use sulfonation to meet the fuel tank permeation standards because it appears to be the most cost effective strategy in most cases. Although barrier platelets and fluorination could likely be applied earlier, we believe that we are providing adequate lead time for manufacturers to incorporate sulfonation into their commercial processes.

5.2.3.2 Operating Cost Savings

5.2.3.2.1 Snowmobiles

Both direct injection and conversion from two-stroke to 4-stroke yield substantial fuel economy benefits. Typical 2-stroke engines have relatively poor fuel economy performance because a portion of the combustion mixture passes through the engines unburned. Because 4-stroke and direct injection 2-stroke engine designs essentially do not allow this to occur, they provide better fuel economy as well as substantially lower HC emissions. We have estimated fuel savings based on a 25 percent reduction in fuel consumption, based on typical performance of these technologies. Lifetime fuel costs are provided in Table 5.2.3-14.[22, 23]

Table 5.2.3-14: Fuel Cost for Snowmobiles

Engine	Baseline 2-Stroke		Advanced Technology Engines (25% savings)	
	small	large	small	large
Engine power	45	100	45	100
Load Factor	0.34	0.34	0.34	0.34
Annual Operating Hours, hr/yr	57	57	57	57
Lifetime, yr	12	12	12	12
BSFC, lb/bhp-hr	1.66	1.25	1.66	1.25
Fuel Density (lbs/gal)	6.17	6.17	6.17	6.17
Fuel Cost ($/gal)*	$1.10	$1.10	$1.10	$1.10
Yearly Fuel Consumption (gal/yr)	235	521	176	391
Yearly Fuel Cost ($/yr)	$258	$574	$194	$430
Lifetime Fuel Cost (NPV)	**$2,050**	**$4,556**	**$1,537**	**$3,417**

* Excluding taxes

5.2.3.2.2 ATVs and Off-highway Motorcycles

Conversion from 2-stroke to 4-stroke engines yields a fuel economy improvement for ATVs and off-highway motorcycles as well. Tables 5.2.3-15 and 5.2.3-16 provide estimates of fuel consumption for both 2-stroke and 4-stroke engines. We have estimated that switching from a 2-stroke to a 4-stroke engine reduces fuel consumption by about 25 percent. Lifetime fuel savings for ATVs resulting from switching from a 2-stroke to a 4-stroke engine is estimated to be $124. For off-highway motorcycles, the projected lifetime fuel savings is $140.

Table 5.2.3-15: Fuel Cost for ATVs

Engine	2-Stroke	4-Stroke
Annual Miles	1,570	1,570
Lifetime, yr	13	13
BSFC, lb/mile	0.213	0.160
Fuel Density (lbs/gal)	6.17	6.17
Fuel Cost ($/gal)*	$1.10	$1.10
Yearly Fuel Consumption (gal/yr)	54	41
Yearly Fuel Cost ($/yr)	$60	$45
Lifetime Fuel Cost (NPV)	**$498**	**$374**

* Excluding taxes

Table 5.2.3-16: Fuel Cost Savings for Off-highway Motorcycles

Engine	2-Stroke	4-Stroke
Annual Miles	1,600	1,600
Lifetime, yr	12	12
BSFC, lb/mile	0.268	0.201
Fuel Density (lbs/gal)	6.17	6.17
Fuel Cost ($/gal)*	$1.10	$1.10
Yearly Fuel Consumption (gal/yr)	68	52
Yearly Fuel Cost ($/yr)	$75	$57
Lifetime Fuel Cost (NPV)	**$594**	**$454**

* Excluding taxes

5.2.3.2.3 Permeation Control Fuel Savings

Evaporative emissions are essentially fuel that is lost to the atmosphere. Over a the lifetime of a typical recreational vehicle, this can result in a significant loss in fuel. The anticipated reduction in evaporative emissions due to the permeation standards will result in significant fuel savings. Table 5.2.3-17 presents the value of the fuel savings for control of permeation emissions. These numbers are calculated using an estimated fuel cost of $1.10 per gallon and fuel density of 6 lbs/gallon (for lighter hydrocarbons which evaporate first). The figures in Table 5.2.3-17 are based on the per vehicle emissions described in Chapter 6.

Table 5.2.3-17: Fuel Savings Per Vehicle Due to the Proposed Standards

Average Parameters	Snowmobiles	ATVs	OHMCs
Evaporative HC reduced [tons/life] Fuel savings [gallons/life] Undiscounted savings [$/life @$1.10/gal]	0.0396 13 $14	0.0221 7 $8	0.0177 6 $6
Lifetime fuel savings (NPV, 7%)	$11	$6	$5

5.2.3.3 Compliance Costs

We estimate ATV and off-highway motorcycle chassis-based certification to cost about $25,000 per engine line, including $10,000 for engineering and clerical work and $15,000 for durability and certification testing. For snowmobile engine-based certification, we estimate costs to be about $30,000, recognizing that engine testing is somewhat more expensive than vehicle testing due to the time needed to set up the engine on the test stand. As with other fixed costs, we amortized the cost over 5 years of engine sales to calculate per unit certification costs shown in Table 5.2.3-18. The actual certification costs for ATVs and off-highway motorcycles are likely to be lower than those shown in the table above because manufacturers are likely to use certification data generated for the California program.

Table 5.2.3-18: Estimated Per Unit Certification Costs

	Snowmobiles	ATVs		Off-highway Motorcycles
units/year/family	4,400	5,600	20,000	6,000
certification costs	$1.78	$1.17	$0.21	$1.09

We have estimated that manufacturers must test about 0.2 percent of their production to meet production-line testing requirements. Using per test costs of $2,500 for vehicle testing and $5,000 per test for engine testing, we estimate a per unit cost for production line testing of $5 for off-road motorcycles and ATVs and $10 for snowmobiles.

In general, we expect manufacturers to use existing test facilities. For manufacturers with insufficient chassis testing capabilities for ATVs, we expect them to carry over engine-based certifications from the California program during the transition period, but to phase-in chassis-based certification during the transition time frame. Because the option of engine-based testing is available for only three years, manufacturers will need to do chassis testing of ATVs by 2009. We have therefore estimated the cost of new chassis testing facilities to be included in the cost of the standards. The costs are based on an estimate provided by one manufacturer that a full test cell would cost $2 million to build. We have estimated that on average manufacturers will need two such facilities to conduct testing. The costs will vary somewhat among manufacturers depending on the state of their existing facilities and the number of vehicle families that must be certified. However, we believe that this is a generous estimate because some manufacturers will likely be able to upgrade existing test facilities instead of building new facilities.

By estimating $4 million per manufacturer, with 7 manufacturers, and amortizing the costs over 10 years (10 years x 729,000 units), we estimate an average per unit cost of $6.70. We have used 10 years for amortization rather than 5 years because we believe it is more representative for a capital investment that will be used at least that long.

5.2.3.4 Recreational Vehicle Total Costs

The analysis below combines the costs estimated above for various technologies into a total composite or average cost for each vehicle type. The composite analysis weights the costs by projecting the percentage of the use of various technologies, both in the baseline and control scenario, to project industry-wide average per vehicle costs. The technologies and the mix projections are discussed in Chapter 4 and are based largely on discussions with individual manufacturers and in some cases on confidential business information.

A summary of the estimated near-term and long-term per unit average incremental costs and fuel savings for recreational vehicles is provided in Table 5.2.3-19. Long-term costs do not include fixed costs, which are retired, and include cost reductions due to the learning curve.

Table 5.2.3-19: Total Average Per Unit Costs and Fuel Savings

	Snowmobile Phase 1	Snowmobile Phase 2	Snowmobile Phase 3	ATV	Off-highway Motorcycle
near-term costs	$80	$131	$89	$87	$158
long-term costs	$47	$77	$54	$45	$98
fuel savings (NPV)	($67)	($286)	($191)	($29)	($53)

Tables 5.2.3-20 through 5.2.3-24 provide the detailed average, or composite, per unit costs for snowmobiles, ATVs, and off-highway motorcycles. For snowmobiles, where there are three phases of standards, the costs are incremental to the previous standard. The composite costs are based on the estimated distribution of the different engine displacement ranges. We estimated an approximate distribution of sales among the displacement ranges using limited sales data provided by some manufacturers on a confidential basis and production data from Power Systems Research. Incremental costs are shown both for the near-term and long-term. Long term costs reflect the retirement of fixed costs and the affect of the learning curve, described in section 5.1.

Table 5.2.3-20: Estimated Average Costs For Snowmobiles (Phase 1)

		Cost	Lifetime Fuel Savings	Baseline	Phase 1	Incrementa l Cost	Incremental Fuel Savings
< 500 cc (30%)	engine modifications	$18	$0	0%	60%	$11	$0
	modified carburetor	$18	$0	0%	60%	$11	$0
	direct injection*	$328	($512)	7%	10%	$10	($15)
	electronic fuel injection	$175	$0	12%	15%	$5	$0
	4-stroke engine	$455	($512)	7%	10%	$14	($15)
	permeation control	$7	($11)	0%	100%	$7	($11)
	compliance	$12	--	0%	100%	$12	$0
	total	--	--	--	--	$69	($41)
≥ 500 cc (70%)	engine modifications	$25	$0	0%	60%	$15	$0
	modified carburetor	$24	$0	0%	60%	$14	$0
	direct injection*	$295	($1,139)	7%	10%	$9	($34)
	electronic fuel injection	$119	$0	12%	15%	$4	$0
	4-stroke engine	$770	($1,139)	7%	10%	$23	($34)
	permeation control	$7	($11)	0%	100%	$7	($11)
	compliance	$12	$0	0%	100%	$12	$0
	total	--	--	--	--	$84	($79)
Near Term Composite Incremental Cost		--	--	--	--	**$80**	**($67)**
Long Term Composite Incremental Cost		--	--	--	--	**$47**	**($67)**

Table 5.2.3-21: Estimated Average Costs For Snowmobiles For Phase 2 Incremental to Phase 1

		Cost	Lifetime Fuel Savings	Phase 1	Phase 2	Incrementa l Cost	Incremental Fuel Savings
< 500 cc (30%)	pulse air/recalibration	$41	$0	0%	30%	$12	$0
	direct injection*	$328	($512)	10%	35%	$82	($128)
	electronic fuel injection	$175	$0	15%	20%	$9	$0
	4-stroke engine	$455	($512)	10%	15%	$23	($26)
	certification	$2	--	0%	100%	$2	$0
	total	--	--	--	--	$128	($154)
≥ 500 cc (70%)	pulse air/recalibration	$41	$0	0%	30%	$12	$0
	direct injection*	$295	($1,139)	10%	35%	$74	($285)
	electronic fuel injection	$119	$0	15%	20%	$6	$0
	4-stroke engine	$770	($1,139)	10%	15%	$39	($57)
	certification	$2	--	0%	100%	$2	$0
	total	--	--	--	--	$132	($342)
Near Term Composite Incremental Cost		--	--	--	--	$131	($286)
Long Term Composite Incremental Cost		--	--	--	--	$77	($286)

* Direct injection costs are an average of the air-assisted and pump assisted system costs.

Table 5.2.3-22: Estimated Average Costs For Snowmobiles Phase 3 Incremental to Phase 2

		Cost	Lifetime Fuel Savings	Phase 2	Phase 3	Incremental Cost	Incremental Fuel Savings
< 500 cc (30%)	pulse air/recalibration	$41	$0	30%	30%	$0	$0
	direct injection*	$328	($512)	35%	50%	$49	($77)
	electronic fuel injection	$175	$0	20%	25%	$9	$0
	4-stroke engine	$455	($512)	15%	20%	$23	($26)
	certification	$2	--	0%	100%	$2	$0
	total	--	--	--	--	$83	($103)
≥ 500 cc (70%)	pulse air/recalibration	$41	$0	30%	30%	$0	$0
	direct injection*	$295	($1,139)	35%	50%	$44	($171)
	electronic fuel injection	$119	$0	20%	25%	$6	$0
	4-stroke engine	$770	($1,139)	15%	20%	$39	($57)
	certification	$2	--	0%	100%	$2	$0
	total	--	--	--	--	$91	($228)
Near Term Composite Incremental Cost		--	--	--	--	**$89**	**($191)**
Long Term Composite Incremental Cost		--	--	--	--	**$54**	**($191)**

* Direct injection costs are an average of the air-assisted and pump assisted system costs.

Table 5.2.3-23: Estimated Average Costs For ATVs

		Cost	Lifetime Fuel Savings (NPV)	Baseline	Control	Incrementa l Cost	Incremental Fuel Savings (NPV)
< 200 cc (15%)	4-stroke engine	$219	($124)	8%	100%	$202	($114)
	pulse air	$33	$0	0%	50%	$17	$0
	R&D for exhaust including recalibration	$16	$0	0%	100%	$16	$0
	permeation control	$3	($6)	0%	100%	$3	($6)
	compliance	$13	--	0%	100%	$13	--
	total	--	--	--	--	$251	($119)
> 200 cc (85%)	4-stroke engine	$349	($124)	93%	100%	$24	($9)
	pulse air/recalibration	$27	$0	0%	50%	$14	$0
	R&D for exhaust including recalibration	$5	$0	0%	100%	$5	$0
	permeation control	$3	($6)	0%	100%	$3	($6)
	compliance	$12	--	0%	100%	$12	--
	total	--	--	--	--	$58	($14)
Near Term Composite Incremental Cost		--	--	--	--	**$87**	**($29)**
Long Term Composite Incremental Cost		--	--	--	--	**$45**	**($29)**

Table 5.2.3-24: Estimated Average Costs For Off-highway Motorcycles (Non-competition models only)

		Cost	Lifetime Fuel Savings (NPV)	Baseline	Control	Incremental Cost	Incremental Fuel Savings (NPV)
< 125 cc (37%)	4-stroke engine	$219	($140)	82%	100%	$39	($11)
	pulse air/recalibration	$39	$0	0%	25%	$10	$0
	permeation control	$3	($5)	0%	100%	$3	($5)
	compliance	$7	--	0%	100%	$7	--
	total	--	--	--	--	$59	($16)
125 < 250 cc (21%)	4-stroke engine	$286	($140)	30%	100%	$200	($98)
	pulse air/recalibration	$39	$0	0%	25%	$10	$0
	permeation control	$3	($5)	0%	100%	$3	($5)
	compliance	$7	--	0%	100%	$7	--
	total	--	--	--	--	$220	($103)
≥ 250 cc (42%)	4-stroke engine	$353	($140)	45%	100%	$194	($77)
	pulse air/recalibration	$39	$0	0%	25%	$10	$0
	permeation control	$3	($5)	0%	100%	$3	($5)
	compliance	$7	--	0%	100%	$7	--
	total					$214	($82)
Near Term Composite Incremental Cost		--	--	--	--	**$158**	**($53)**
Long Term Composite Incremental Cost		--	--	--	--	**$98**	**($53)**

The above table for off-highway motorcycles shows the anticipated split between two-stroke and 4-stroke models in the various engine size categories. Currently, off-highway motorcycles are about 63 percent 2-stroke with many of the 2-stroke engines used in competition and youth models. In recent years, more high performance and competition models have been successfully introduced with 4-stroke engines and there appears to be a trend toward increased use of 4-stroke engines. Models used solely for competition are exempt from emission standards. We expect some 2-stroke competition models to continue to be available under this exemption. For purposes of the cost analysis, we have estimated that 29 percent of all off-highway motorcycles will be exempt as competition models and that these models will be equipped with 2-stroke engines. We have based the estimate of exempt models on the our estimate of the current use of 2-strokes in the motocross market. We believe the emissions standards will be achievable for 4-stroke engines, especially with averaging, and that manufacturers would elect to certify all 4-stroke models to market them to the widest possible consumer base.

To account for the competition model exemption in the calculation of average costs, we have adjusted the percentage of 2-stroke engines from the overall baseline percentage of off-highway motorcycle sales using the 29 percent estimate noted above. This adjustment is necessary to determine average costs only for those off-highway motorcycles covered by the program. Table 5.2.3-25 provides our estimate of the baseline percentage of 2-strokes in overall sales and the percentage of the non-competition model sales.

Table 5.2.3-25: Estimated Off-highway Motorcycle Percent 2-stroke Engine Usage

Displacement	Overall Baseline 2-stroke percentage	Baseline 2-stroke percentage Excluding Competition Models
< 125 cc	42%	18%
125 to 249 cc	79%	70%
> 250 cc	68%	55%

5.2.3.5 Recreational Vehicle Aggregate Costs

The above analyses developed incremental per vehicle cost estimates for snowmobiles, ATVs, and off-highway motorcycles. Using these per vehicle costs and projections of future annual sales, we have estimated total aggregate annual costs for the recreational vehicles standards. The aggregate costs are presented on a cash flow basis, with hardware and fixed costs incurred in the year the vehicle is sold and fuel savings occurring as the vehicle is operated over its life. This may understate the time-value of the fixed costs because they are likely to be incurred before the vehicle is sold; however, this has a negligible effect on the results of this analysis. Table 5.2.3-26 presents a summary o f the results of this analysis. As shown in the table, aggregate net costs increase from about $65 million in 2006 to about $129 million in 2010.

Net costs are projected then to decline as fuel savings continue to ramp-up as more vehicles meeting the standards are sold and used and fixed costs are amortized. Fuel savings are projected to more than offset the costs of the program starting in 2015.

Table 5.2.3-26
Summary of Annual Aggregate Costs and Fuel Savings (millions of dollars)

	2006	2010	2015	2020	2025
Snowmobiles	$6.58	$37.55	$41.91	$41.56	$41.56
ATVs	$42.46	$62.55	$49.69	$44.81	$44.81
Off-highway Motorcycles	$16.27	$24.24	$21.53	$22.63	$23.79
Permeation control	--	$4.59	$4.72	$4.83	$4.86
Total	$65.31	$128.93	$117.85	$113.83	$115.02
Fuel Savings	($1.60)	($39.90)	($121.70)	($187.00)	($212.60)
Net Costs	$63.71	$89.03	($3.85)	($73.17)	($97.58)

To project annual sales, we started with 2001 sales estimates provided by industry organizations. We then adjusted the numbers and applied sales growth estimates consistent with the modeling performed to estimate total emissions (see Section 6.2.4.1.1). For ATVs, we added 70,000 units to account for sales from companies not included in the industry organization estimates. Sales growth for snowmobiles and off-highway motorcycle sales is projected to be about one percent per year. The off-road motorcycle sales were reduced by 29 percent to account for the exemption of competition models. ATVs are modeled differently because recent sales growth rates have been significantly higher than one percent but are at rates not likely to be sustained indefinitely. We project that ATV sales will continue to grow at a higher rate over the next few years but will level off by 2006. Table 5.2.3-27 provides a summary of the sales estimates used in the aggregate cost analysis.

Table 5.2.3-27: Estimated Annual Recreational Vehicle Sales

	2001	2006	2010	2020
Snowmobiles	140,629	189,497	210,367	240,162
ATVs	880,000	985,754	985,754	985,754
Off-highway motorcycles*	195,250	205,210	213,542	235,883

* Non-competition only

To calculated annual aggregate costs, the sales estimates have been multiplied by the per unit costs. Fuel savings have been calculated using the NONROAD model to calculate the shift in use from 2-stroke to 4-stroke vehicles, and also direct injection 2-strokes for snowmobiles, over time. The model takes into consideration vehicle sales and scrappage rates. The standards phase-in schedule for off-highway motorcycles and ATVs (50/100% in 2006/2007) has also been taken into account. The detailed year-by-year analysis is provided in Chapter 7.

Chapter 5 References

1."Update of EPA's Motor Vehicle Emission Control Equipment Retail Price Equivalent (RPE) Calculation Formula," Jack Faucett Associates, Report No. JACKFAU-85-322-3, September 1985 (Docket A-2000-01, document II-A-54).

2.For further information on learning curves, see Chapter 5 of the Economic Impact, from Regulatory Impact Analysis - Control if Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements, EPA420-R-99-023, December 1999. A copy of this document is included in Air Docket A-2000-01, at Document No. II-A-83. The interested reader should also refer to previous final rules for Tier 2 highway vehicles (65 FR 6698, February 10, 2000), marine diesel engines (64 FR 73300, December 29, 1999), nonroad diesel engines (63 FR 56968, October 23, 1998), and highway diesel engines (62 FR 54694, October 21, 1997).

3."Estimated Economic Impact of New Emission Standards for Heavy-Duty Highway Engines," by Lou Browning, Acurex Environmental Corporation Final Report (FR 97-103), March 31, 1997, Docket A-2000-01, document II-A-51.

4."Incremental Costs for Nonroad Engines: Mechanical to Electronic," Memorandum from Lou Browning, Acurex Environmental, to Alan Stout, EPA, April 1, 1997 (Docket A-2000-01, document II-A-52).

5."Incremental Cost Estimates for Marine Diesel Engine Technology Improvements," Memorandum from Louis Browning and Kassandra Genovesi, Arcadis Geraghty & Miller, to Alan Stout, EPA, September 30, 1998 (Docket A-2000-01, document II-A-53).

6."Large SI Engine Technologies and Costs," by Lou Browning, Arthur D. Little - Acurex Environmental, Final Report, September 2000, Docket A-2000-01, document II-A-15.

7. "Exhaust Controls Available to Reduce Emissions from Nonroad Heavy-Duty Engines," in Clean Air Technology News, Winter 1997, p. 1 (Docket A-98-01; item II-A-02).

8. "It's Not Easy Being Green," Modern Materials Handling, April 2000 (Docket A-2000-01; item II-A-06).

9. Letter from William Platz, Western Propane Gas Association, January 24, 2001 (Docket A-2000-01; item II-D-40).

10. "It's Not Easy Being Green," Modern Materials Handling, April 2000 (Docket A-2000-01; item II-A-06).

11. "Nonroad Recreational Vehicle Technologies and Costs", Arthur D. Little - Acurex Environmental, Draft Final Report, July 2001 (Docket A-2000-01, document II-A-31)..

12. “Nonroad Recreational Vehicle Technologies and Costs”, Arthur D. Little - Acurex Environmental, Draft Final Report, July 2001 (Docket A-2000-01, document II-A-31).

13. “Nonroad Recreational Vehicle Technologies and Costs”, Arthur D. Little - Acurex Environmental, Draft Final Report, July 2001 (Docket A-2000-01, document II-A-31).

14. “Information on Costs and Effectiveness of Fluorination Received from Fluoroseal,” Memorandum from Mike Samulski to Docket A-2000-1, March 27, 2002, Docket A-2000-01, Document IV-B-03.

15. “Visit to Sulfo Technologies LLC on April 18, 2002,” Memorandum from Mike Samulski, U.S. EPA to Docket A-2000-01, April 22, 2002, Document IV-B-07.

16. “Shipping Costs,” Memorandum from Glenn Passavant, U.S. EPA to Docket A-2000-01, March 27, 2002, Document IV-B-01.

17. Trident Marine Hose, “Retail Price List 2001,” Docket A-2000-01, Document No. IV-A-15.

18. Denbow, R., Browning, L., Coleman, D., “Report Submitted for WA 2-9, Evaluation of the Costs and Capabilities of Vehicle Evaporative Emission Control Technologies,” ICF, ARCADIS Geraghty & Miller, March 22, 1999, Docket A-2000-01, Document No. IV-B-05.

19. “Meeting with Avon on June 27, 2002,” Memorandum from Mike Samulski, U.S. EPA to Docket A-2000-01, August 6, 2002, Docket A-2000-01, Document IV-E-33.

20. Denbow, R., Browning, L., Coleman, D., “Report Submitted for WA 2-9, Evaluation of the Costs and Capabilities of Vehicle Evaporative Emission Control Technologies,” ICF, ARCADIS Geraghty & Miller, March 22, 1999, Docket A-2000-01, Document No. IV-B-05.

21. “Visit to Sulfo Technologies LLC on April 18, 2002,” Memorandum from Mike Samulski, U.S. EPA to Docket A-2000-01, April 22, 2002, Document IV-B-07.

22. Brake-specific fuel consumption (BSFC) based on 4-stroke BSFC estimates provided by Power Systems Research.

23. “Monthly Energy Review”, Calendar year 2000 average Refiner Prices of Petroleum Products to End Users (Cents per gallon, excluding taxes), Energy Information Administration.