CALIFORNIA
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SAFE SCHOOL BUS CLEAN FUEL EFFICIENCY DEMONSTRATION PROGRAM

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Executive Summary

This report is the final report on Phase 4 of the Safe School Bus Clean Fuel Efficiency Demonstration Program (School Bus Program) created by Assembly Bill 35 (Part 10.7, California Education Code, Section 17910 et seq.) and sponsored by Assemblyman Richard Katz. The four-phase program was designed to replace school buses manufactured prior to 1977 - the year federal minimum safety standards were made more stringent - at least 35 percent of which use clean burning, low-emission fuels. This report summarizes the major successes and challenges of the School Bus Program and provides a glimpse at the future of alternative fuels both for school buses and at large.

The program's primary objective was to conduct a demonstration of new school buses that met all applicable Federal Motor Vehicle Safety Standards, produced fewer adverse air emissions, and operated with greater energy efficiency than the vehicles being replaced. The 49 compressed natural gas buses from Phase 4 displace approximately 4 to 9 million gallons of diesel per year, with a yearly average displacement of 6 million diesel gallons, and emit approximately 22 fewer tons of oxides of nitrogen (NO_x) into the atmosphere each year. As shown, the program achieved its objectives through enhanced safety, reduced emissions, and displacement petroleum.

In addition, the program also addressed several secondary objectives that support the Energy Policy Act (EPACT) of 1992. These objectives included the promotion of new clean-fuel vehicle industries, the formation of partnerships, development of fueling infrastructure throughout the State; and education of personnel of local education agencies about alternative fuels. The School Bus Program succeeded in these areas, helping to make California the leader in the United States for clean vehicle operation, in addition to lessening California's dependence on foreign oil. Most importantly, by actively providing development of alternative fuel industries and educating local officials, this program planted seeds that continue to grow and provide health and safety benefits for future generations of Californians.

Through the California Energy Commission (Energy Commission), the original four-phase program used money from the Petroleum Violation Escrow Account to place a total of 826 buses in service across the State. Compressed natural gas is now an alternative fuel of choice by local education agency operators.

Type and Number of Buses Placed

	Advanced Diesel	Methanol	Compressed Natural Gas
Phase 1	103	50	10
Phase 2	200	100	100
Phase 3	107	0	107
Phase 4	0	0	49

Chapter 1

Safe School Bus Clean Fuel Efficiency Demonstration Program

Objective

The objective of the School Bus Program was to conduct a demonstration of new school buses that meet all applicable Federal Motor Vehicle Safety Standards (FMVSS), produce fewer vehicle emissions, and displace petroleum use in transportation through efficiency improvements and alternative fuels.

Background

The School Bus Program began with the enactment of AB 35 (Part 10.7, California Education Code, Section 17910 et seq.). The Legislature found that 30 percent of publicly owned school buses in California had been manufactured prior to April 1977, when the federal government imposed more stringent minimum safety standards for school buses. Not only did these old buses lack desirable advanced safety features, they also had high repair costs, produced excessive air pollution, and consumed large amounts of petroleum fuel. To improve safety for California's school children, while at the same time addressing the State's energy and environmental concerns, the Legislature authorized this demonstration program to replace the pre-1977 buses with new ones that met or exceeded current FMVSS, operated with greater energy efficiency, and produced fewer adverse air emissions.

To implement the program, the Legislature funded the School Bus Program at $100 million from the Petroleum Violation Escrow Act (PVEA). A settlement over allegations that the oil companies had overcharged their customers in the 1970s resulted in the oil companies paying money into the PVEA account. These PVEA funds were collected and dispersed by the federal government. Because PVEA funds are reserved for projects that encourage energy independence (through fuel diversification), a minimum of 35 percent of the bus replacement fleet were to be operated on alternative fuels such as methanol and compressed natural gas. Although the Katz School Bus Program accomplished its objectives, PVEA funds were insufficient to cover the expense of replacing all of the pre-1977 school buses in California, and many pre-1977 school buses remain on the road.

The Energy Commission, in cooperation with the California Highway Patrol (CHP) and the California Department of Education (CDE), established a selection protocol to determine which buses would be replaced. Program Opportunity Notices (PONs) were sent to all of the local education agencies (LEAs) in California to inform them of the program. Based on the selection protocol and the information provided by the LEAs in the PON responses, demonstration sites were selected and pre-1977 school buses at those sites were chosen for replacement. When an LEA accepted a replacement school bus, it agreed to maintain records of that bus' mileage and fuel consumption, and report that information to the Energy Commission throughout the five-year demonstration period of each phase. The phases did not run consecutively, rather some overlap in timing occurred.

A Phased Approach

Not all buses were delivered to the LEAs at the same time. Instead, the Energy Commission used a phased approach to implement the School Bus Program, so that experience gained in one phase of the demonstration could be applied to the next. Significant progress was made not only in vehicle and fueling infrastructure technology, but also in streamlining the acquisition process for obtaining these technologies.

Petroleum Displacement

Buses that operate on alternative fuels can reduce California's dependence on foreign petroleum and provide diversity of fuel supply. Natural gas is produced in California and the rest of the United States. Using this fuel supports the economy and potentially provides insulation against rises in crude oil prices.

The program resulted in energy efficiency gains of new school buses. Petroleum usage per decreased due to improved energy efficiency of the advanced diesel bus engines. Buses operating on compressed natural gas completely replaced petroleum. The 49 compressed natural gas buses awarded in Phase 4 displaced approximately 4 to 9 million gallons of diesel per year, with an average annual displacement of 6 million diesel gallons.

Emission Reductions

Children are particularly sensitive to diesel emissions and are exposed to high levels of pollutants when riding buses regularly. The buses from this program run cleaner and emit fewer pollutants per mile than older diesel buses they replace, thereby reducing children's exposure to pollutants. Technologies such as advanced diesel and natural gas reduce emissions.[1] On average, the 49 compressed natural gas buses emit approximately 22 fewer tons of oxides of nitrogen (NO_x) into the atmosphere each year, when compared to older diesel buses.

Improvements in the air quality resulting from this program benefit everyone in the community, especially school children.

Alternative Fuels are Safe

At the beginning of the program many parties expressed extreme concern about the safety of alternative fuels in transportation applications. Much of this concern stemmed from a lack of familiarity with these fuels. Initially, certain aspects of alternative fuels appeared to have genuine safety concerns.

Compressed natural gas, for example, caused concern because the high pressure required gas storage. During the course of the program there were isolated incidents of tanks

[1] Refer to Second Interim Report.

rupturing on a compressed natural gas pickup and a transit bus. Extensive industry and government studies determined that the tanks failed as a result of careless installation or poor design of the tank storage areas.

These events prompted a safety review on all compressed natural gas school buses in California. Many such buses across the country were also inspected to determine if the storage cylinders were damaged or if the cylinders were improperly installed. The LEAs inspected all of the compressed natural gas buses in the Katz Program and found no problems with the tanks. As a result, the California Highway Patrol (CHP) now inspects the school buses at regular intervals. Because of these precautions, and because the program experienced not a single case of cylinder failure throughout its nearly 12-year duration, the program helped to prove that the equipment is safe, and it is now considered mainstream technology.

Chapter 2

Advanced Technology in New School Buses

Demonstrating New Technologies

The demonstration of advanced safety features and alternative fueled engines and vehicles played a key role in bringing new technologies to the commercial arena in California. Through the School Bus Program, the introduction of alternative fuels, along with advanced safety and diesel engine technologies, were accelerated for application to California school buses. Also through this program, manufacturers provided unique and advanced products that otherwise might not yet be available.

In this program, as in any demonstration program, the test platforms serve to showcase the new technologies demonstrated. The school buses were built with many new safety, fuel, and engine technologies that were implemented for the first time.

Safety Features of the New School Buses

One concern of this program was to ensure the safety of California's school children whenever they travel in school buses. Safety was the foremost concern in the development of the program's bus chassis and engine specifications. The Energy Commission - in consultation with the California Highway Patrol (CHP), Department of General Services (DGS), and the California Department of Education (CDE) - developed these specifications. The specifications met and exceeded both federal and current state specifications. Because of this program, California now receives safer school buses than otherwise would have been possible.

Aside from meeting all of the current applicable FMVSS, the major improvements to previous state school bus specifications included the following areas:

- fire suppression systems
- additional emergency exits
- increased window size
- traffic warning system
- transit front window design
- anti-lock braking systems
- automatic parking brake
- flame-retardant seats
- raised fully padded seatbacks
- methane leak detectors on natural gas buses.

All of the improved safety features incorporated as a result of this program represent the priority of the Energy Commission, the CDE, and the CHP to protect the state's school children with the latest and most advanced technologies.

For further assurance that the advanced technology provides for safe operation, buses were subjected to various performance tests, including durability, braking, and crash tests. In addition, special crash testing of the methanol and compressed natural gas buses was performed to address concerns over fuel tank safety. The buses passed all of these tests.

New Fuel and Engine Technologies

Advanced fuel and engine technologies were other featured characteristics of the new school buses. The specific equipment developed for the program was implemented during different phases.

Phase 1

The Phase 1 buses demonstrated methanol, natural gas, and advanced diesel engines. The advanced diesel buses were Crown Coach chassis with Detroit Diesel Corporation 6V-92TA engines. A non-turbocharged version of Tecogen's Tecodrive 7000 engine utilized natural gas fuel. During the program, the Tecogen engine with a gasoline block was found to be underpowered for the application, and experienced some difficulty during periods of quick acceleration onto freeways and up hills.

Phase 2

In Phase 2, the number of buses demonstrated was increased to better evaluate the technologies. A Caterpillar 3116TA engine with an oxidizing catalyst was used. The Detroit Diesel 6V-92TA methonol engine remained the same with the addition of an oxidizing catalyst for reduced emissions. The Tecogen engine also remained the same, but added a turbo-charger. Although the turbocharger provided more power, it tended to overheat causing engine malfunctions and increasing downtime and maintenance costs.

Phase 3

By Phase 3, the school buses were in an advanced stage of development, compared to their Phase 2 counterparts, and all parts, equipment, and accessories were completely installed and assembled by a single manufacturer, Blue Bird. Phase 3 included advanced diesel and natural gas buses, and the program anticipated the introduction of electric buses as well. For Phase 3, no engine or bus manufacturer offered methanol as an alternative fuel option.

Because of the overheating issues that hampered the Tecogen Tecdrive 7000 engine in Phase 2, Blue Bird asked for a bid from John Deere for a compressed natural gas engine for Phase 3. John Deere developed this engine to operate on compressed natural gas and installed an advanced electronic control system. The John Deere engine was based upon a diesel engine block engineered for compressed natural gas, whereas the Tecogen compressed natural gas engine was a gasoline-block converted to operate on compressed natural gas. By Phase 3, compressed natural gas technology proved very successful John Deere's commitment led to this success.

Phase 4
Phase 4 implemented 49 compressed natural gas buses. The compressed natural gas bus has become popular among the LEAs and is one of the top choices when LEAs seek to purchase a new bus. During this phase, the most common problem was a cold-start or no-start problem. The LEAs that experienced this problem worked with the manufacturer to resolve this problem.

(For additional details on the results of each Phase, see Safe School Bus Clean Fuel Efficiency Demonstration Program Second Interim Report prepared May 1999.)

Electric Buses

Electric buses were not purchased in the Safe School Bus Clean Fuel Efficiency Demonstration Program because the technology was not available in the timeframe required. At a later date, three LEAs purchased electric buses in cooperation with their respective air quality management districts. However, these electric buses were not part of the Safe School Bus Clean Efficiency Demonstration Program.

Technology Push

The School Bus Program pushed advanced safety features, diesel and alternative-fuel technologies beyond what was currently available at the time, and beyond what industry had planned to develop. The commercialization of heavy-duty alternative fuel engines and fuel systems is one long-term legacy of the program. This technology is available not only for school buses but is now available for other applications across the State.

Technology Summary

Fuel Technology	No. of Buses	Coach Builder	Engine
		PHASE 1	
Advanced diesel	103	Crown Coach	DDC 6V-92TA with Electronic engine controls
Methanol	50	Crown Coach	DDC 6V-92TA with Electronic engine controls
Compressed natural gas	10	Blue Bird	Tecodrive 700 (retrofitted to John Deere)
		PHASE 2	
Advanced diesel	200	Thomas Built	Caterpillar 3116 TA
Methanol	100	Carpenter	DDC 6V-92TA methanol with Electronic engine controls
Compressed natural gas	100	Blue Bird	Tecodrive 7000 with turbocharger (retrofitted to John Deere)
		PHASE 3	
Advanced diesel	107	Blue Bird	Caterpillar 3126 TA
Compressed natural gas	107	Blue Bird	John Deere 450 6081 HFN
		PHASE 4	
Compressed natural gas	49	Blue Bird	John Deere 450 6081 HFN

Cost Reductions

During the course of this demonstration program, costs for the compressed natural gas package were reduced. Phase 1 compressed natural gas Crown buses cost approximately $150,000, including the compressed natural gas package. The compressed natural gas package includes the compressed natural gas engine, fire suppression unit, four compressed natural gas tanks, and fuel delivery system. For Phase 2 the compressed natural gas package cost $34,722. By Phase 4 of the program, the compressed natural gas package cost $29,269. The current compressed natural gas package costs $29,616, a 14 percent reduction since Phase 2.

Bus Prices During the Program

	Cost of Compressed Natural Gas Bus	**Cost of Diesel Bus**
Phase 1	$150,000	$129,000
Phase 2	$117,500	$83,000
Phase 3	$100,000	$87,500
Phase 4	$122,200	$92,900[2]

[2] Although there were no diesel buses awarded during Phase 4, this reflects the approximate cost of a diesel bus at the time.

Chapter 3

Facing the Challenges of the School

Bus Program Overview

The School Bus Program accomplished its goals and endured many difficulties throughout its history. The previous chapters highlighted the achievements made toward realizing the primary objectives of this program. This chapter will discuss the daily operation of the buses, and describe specific challenges and hardships that were overcome by the program's participants.

Operation of the Buses

At the beginning of each phase, the DGS contracted with the school bus distributors for the purchase of the buses. The dealers were responsible for delivering the buses to the LEAs, and first shipped the buses to the dealers' distribution centers. There, the CHP conducted inspections on the buses before their delivery to the LEAs. Once minor issues such as faulty turn signals were resolved, the buses were shipped to the LEAs.

The Energy Commission was assigned to assist the LEAs, and staff worked with the LEAs to set up a semi-automated system of data collection. The Energy Commission also provided information on the safety of alternative fuels and disseminated information on bus upgrades and maintenance information among the LEAs.

Each of the school buses was required to have warranty support for the chassis and engine. The warranties for the engine and chassis were five years and twenty years, respectively. Although the buses were equipped with advanced engine technologies, the bus specifications and warranty provided a substantial degree of protection to the LEAs from repair expenses. The strict warranty provisions in the bus purchase contracts protected the LEAs from a number of maintenance difficulties. The DGS was responsible for ensuring that warranty obligations were met.

The new school buses, both diesel and alternative-fueled, were used extensively across California's varied terrain and environment, operated on all route types, under all seasonal conditions, and with different drivers. In general, the buses have performed well under these diverse circumstances.

A crucial, but often underestimated, component to the success of alternative fuels in transportation is the supporting fueling infrastructure. The School Bus Program assisted with California's development of methanol and compressed natural gas fueling infrastructure by installing a number of new stations. The Energy Commission contributed program funding to alternative fuel stations, up to $50,000 per station in Phase 1 and up to $10,000 in Phase 2. However, these funds were highly leveraged and the majority of funding for fueling stations came from outside the program. In most cases, the cost of new public fueling facilities was

shared by LEAs, utilities or the local air quality management districts. Better yet, in other cases, the utilities paid for new compressed natural gas stations in full as investments for long-range business plans. In this manner, the program leveraged its funding to build a fueling network that not only supported the new school buses, but also allowed other alternative fueled vehicles to refuel from the network.

To reduce capital expenditures, several LEAs sometimes shared the same fueling site. In other cases, LEAs used public facilities to completely avoid capital costs. These operations require that bus fueling be done offsite by school personnel, increasing operating costs but providing better overall life-cycle costs for those LEAs.

Operational Challenges

Like any technology demonstration, the program faced numerous technical challenges. Although the alternative-fueled buses did not achieve the same operational time during the program as their diesel counterparts, manufacturers improved the durability of successive generations of these buses.

Most of the challenges were related to the use of alternative fuels, but some problems pertained to other facets of the buses. These problems were promptly addressed to ensure that the buses were completely safe for operation. Manufacturers and distributors worked together to address various problems that arose. Without the commitment of the manufacturers and distributors to maintain high quality service, the program would certainly have failed to reach its goals.

The methanol buses experienced several difficulties related to the fuel, fuel systems and engines. Presently, no engine or bus manufacturers offer methanol.

Both the Phase 1 and Phase 2 compressed natural gas buses are powered by Tecogen Tecodrive 7000 engines, which were derived from a light-duty gas engine. These engines were GM 427 tall block engines that lacked enough torque to be used in school buses. These first compressed natural gas engines experienced problems such as lack of power and overheating. However, by Phase 4, the compressed natural gas engine's performance was comparable to that of a diesel engine.

Chapter 4

Program Status and Future Outlook

School Bus Replacements to Date

The School Bus Program, in conjunction with other state and local replacement programs, significantly aided in the retiring of aging buses in California's LEAs. In 1989, roughly 30 percent of the 12,000 Type I school buses in operation in the State were constructed before 1977. By concentrating on replacing the least efficient and most polluting buses, the program achieved the greatest environmental gains with each dollar invested.

Phase 4

The success of the original three-phase program, and specifically the Phase 3 natural gas engines, resulted in implementation of a fourth phase. This phase delivered a total of 49 compressed natural gas buses.

New Programs to Help Replace School Buses

Unfortunately, the PVEA funds upon which the program relied until now are almost depleted, and new funding mechanisms are required in order to continue replacement of California's remaining old school buses. Several new programs helped fill this void. Assembly Bill 3488 (Article 4.7, California Education Code, Section 42300 et seq.), which taps money from the Proposition 98 set-aside for education, continued the tradition of the School Bus Program by allocating these funds toward the replacement of pre-1977 buses. This program leveraged the LEAs' dollars by sharing some of the costs of the new buses. In addition, LEAs interested in new vehicles can also receive assistance from local air quality management district programs that set aside motor vehicle registration fee money to promote clean-fuel transportation. Furthermore, federal money from the Transportation Equity Act is available for the purchase of alternative-fueled school buses. However, funding for the continuation of the School Bus Program is tenuous due to the State's current budget constraints.

Outlook for Alternative Fuels

The future of alternative fuels in the transportation sector is hopeful, but uncertain. Ironically, the natural advantages of these fuels, given their clean-burning characteristics, have slowly eroded as the emissions levels of new diesel engines have improved. As tighter emissions standards are enforced, all fuel technologies, both conventional and alternative, must improve to meet the standards.

To date, diesel technologies have achieved these target levels, requiring alternative fuels to be even cleaner if they are to maintain their "green" advantage. Furthermore, conventional-fueled vehicles have not yet attained their maximum potential fuel economy; experimentation with new drive trains powered by these fuels could reduce emissions to extremely low levels.

Thus, it is unclear today whether any alternative fuel technologies can provide sufficient air quality benefits to distance themselves from cleaner conventional fuels.

On the other hand, alternative fuels have the undeniable advantage of displacing petroleum fuels; conventional fuels can be displaced only by improving vehicle operating efficiency. As this report indicates, each new vehicle on the road powered by natural gas saves a substantial amount of petroleum fuel. Alternative fuels are a powerful weapon that California and the rest of the nation can use to wean themselves from foreign oil and potentially avert future energy crises. Stronger emphasis from policy makers on developing a domestically sustainable energy supply would further boost the technological, industrial and marketplace advances already achieved by alternative fuels. Inevitably, if alternative fuels are to be successful, operators must obtain an economic advantage from using them. The key to achieving this is to translate the environmental benefits into financial incentives that make the life-cycle cost of operation a winning situation.

Natural gas has proven that it can compete with diesel technologies in school bus applications because the savings from lower operating costs can pay back the premium cost of the capital equipment. Furthermore, as time goes on, these engine premiums will decrease as natural gas production increases, making natural gas operation even more affordable. Because of its attributes and its clean air and energy diversification benefits, natural gas has become the fuel of choice for many LEAs and is now seriously considered when LEAs seek to acquire new vehicles. This interest has spurred industry to develop a more complete line of products and, for the first time, engines are now available for a diverse line of vehicles. As diesel engines are made to meet lower emission standards, the engine and exhaust after treatment have added to their purchase cost, bringing the price of diesel and natural gas-powered buses closer together.

Conclusion

The Katz Safe School Bus Clean Fuel Efficiency Demonstration Program has accomplished its primary objective of replacing pre-1977 school buses with vehicles that meet or exceed the current FMVSS, operate with greater energy efficiency and produce fewer adverse air emissions. The new buses have created a safer, cleaner environment for California's school children. However, the benefits reaped by the State will extend far beyond the program itself; the program set the stage for future progress toward a United States fueled by clean, domestic fuels.

During the program, industry moved forward in developing alternative fuel technologies, and product lines matured and expanded, ensuring a stable industrial basis for the future. Particularly impressive, however, is the heightened consciousness in California regarding the benefits and utility of alternative fuels in school bus operations. The participating LEAs learned on-the-job and helped to disseminate this information throughout the State.

Currently, the manufacturers who develop alternative fuel (compressed natural gas) engines, include Caterpillar, John Deere and Cummins. In the alternative fuel industry, Tecogen was the first to promote an alternative fuel engine for the School Bus Program. Although it proved

to be too light and not powerful enough for school bus application Cummins, and later Caterpillar and John Deere, were encouraged to begin production of alternative fuel engines. These engines have all been certified for California Air Resource Board's optional low emission standard. Despite issues early in the program, the demonstration proved that advanced technologies and alternative fuels have a place in today's transportation sector.

The School Bus Program's Legacy

The School Bus Program accomplished its goals of bringing new safe, energy-efficient, and lower-emission school buses to the fleet. Furthermore, the success of the program reached even beyond these objectives by moving clean alternative fuel vehicle technology to commercialization.

The time is right for building upon the foundation provided by the School Bus Program and promoting the continued acquisition of alternative-fueled vehicles by the State's school bus fleet. By emphasizing this new direction, we can make vast steps toward securing a safer, cleaner, more energy-independent future for California and the entire nation.