BIODIESEL VS. OTHER ALTERNATE FUELS
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AGENCY BIODIESEL EXPERIENCE

Approximately two years ago, the Agency began a demonstration project using biodiesel blends in Call-a-Ride vans to evaluate its suitability as a motor fuel. The evaluation revealed that:

- Biodiesel is a viable motor fuel.
- Performance and fuel economy were unchanged.
- Exhaust emissions improved dramatically.
- The fuel was fully compatible with vehicle and fuel dispensing equipment.

Based on these positive results, the Agency expanded the test to the entire paratransit fleet and continued the evaluation. The Agency also tested biodiesel in bus engines on the dynamometer, with technicians from the University of Missouri-Columbia performing emissions tests, again with positive results.

Our experience with biodiesel has caused the Agency to seriously consider how biodiesel can help achieve the requirements mandated by The Clean Air Act Amendments of 1990 and The Urban Bus Retrofit and Rebuild Program. The long term project we have just begun to feed information on biodiesel buses to The National Renewable Energy Laboratory should be of great assistance in planning our future alternate fuel policy.

Since diesel engine emissions technology has improved greatly over the past few years, one compliance scenario would be to purchase new clean diesel buses as old units are removed from service, and to run a 20% biodiesel blend in the entire fleet. This would enable the fleet to comply, through fleet averaging, with the particulate matter reductions mandated in The Clean Air Act, without any infrastructure modifications, extra training, or additional safety precautions. This scenario should be fully explored before any long term, capital intensive commitment is made to any other alternate fuel technology.

To assist in the analysis of available technologies, the Quality Assurance Department has prepared a comparative evaluation of all the viable alternate fuels against baseline diesel power. All of the numerical scores in the evaluation were assigned from the perspective of lowest cost per mile and highest reliability, and solely reflect the views of Quality Assurance.

EVALUATION CRITERIA - 10 = Most Desirable, 0 = Least Desirable

Vehicle Cost - Includes all costs from development of specifications through delivery to the Agency. Factors include production volumes, production man-hours, component costs, on board fire protection systems, delivery costs, and the cost to the Agency of on-line vehicle inspection.

Infrastructure Cost - Includes costs to modify or add equipment for on-site fueling and daily operation. Factors included are engineering and specification development, required redundant systems, required safety systems, and required HVAC modifications.

Safety - Includes toxicity, spill risk, miscibility, flash point, proximity of fuel system to road hazards, and permissible exposure levels.

Operating Cost - Includes non-capital expenses to fuel and operate the vehicle. Factors included are energy costs to operate fueling equipment, maintenance costs on fueling equipment, fuel cost, replacement parts cost, vehicle repair labor and possible permit costs for overweight vehicles.

Reliability - Includes maturity of technology, frequency and severity of unscheduled repairs, and down time.

Customer Acceptance - Customer's views on safety, environmental factors, appearance, comfort, noise, etc.

Funding Assistance - Availability of funding from non-traditional sources for vehicle procurement, facility modifications, fuel costs, etc.

Training Costs - Includes loss in productivity due to "learning curve", training hours for mechanics, facility maintenance personnel, fuelers, and operators.

Fuel Availability - Lead times for delivery, production capabilities, available reserves.

Fuel Quality - Consistent conformity of fuel to engine manufacturer's specifications

Fuel Price Stability - Market factors and procurement policies affecting fuel prices.

OTHER TECHNOLOGIES REVIEWED

Propane - Propane has several advantages, such as good price and availability, consistent quality, mature technology and low emissions. The disadvantages, however, far outweigh the advantages, particularly regarding safety. Propane fumes are heavier than air and have a low flash point, a bad combination if you intend to fuel, store, and repair the vehicles indoors. The seriousness of these safety factors has caused the Agency not to consider propane a viable fuel for our operation.

Particulate Traps - The Agency purchased two particulate trap equipped buses in 1991, and had numerous problems keeping them in service. The trap design on the Agency buses was abandoned by the trap manufacturer in favor of a different design, but units in service today are still experiencing serious operational problems with these units. Due to the high operational expense and immature technology of these units, the Agency is not considering particulate traps as a viable technology at this time.

	DIESEL	CNG	LNG	METHANOL	ETHANOL	BIODIESEL
VEHICLE COST	10	5	5	5	5	10
INFRASTRUCTURE COST	10	2	5	5	5	10
SAFETY	7	4	3	1	3	8
OPERATING RANGE	10	5	10	10	10	10
OPERATING COST	10	5	7	5	5	7
RELIABILITY	10	7	5	3	3	10
CUSTOMER ACCEPTANCE	5	8	8	8	9	8
FUNDING ASSISTANCE	1	10	2	0	2	2
TRAINING COST	10	5	5	5	5	10
FUEL AVAILABILITY	10	10	5	5	5	6
FUEL QUALITY	9	5	10	8	8	9
FUEL PRICE STABILITY	6	8	8	6	6	6
TOTALS	98	74	73	61	66	96

DIESEL

Vehicle Cost - Vehicle cost is the lowest of all available alternatives due to the maturity of the technology and the abundance of manufacturing infrastructure.

Infrastructure Cost - Infrastructure cost is also lowest, as all fueling, HVAC, and safety equipment is in place and operating.

Safety - Diesel fuel has disadvantages in toxicity, spill risk, and flammability.

Operating Range - Diesel, having the highest energy content of all available fuels, provides the farthest operating range with the least amount of on-board fuel storage.

Reliability - Again, due to the maturity of the technology and skill level of the work force, diesel is the most reliable.

Customer Acceptance - Diesel rates are low in customer acceptance due to public perception of diesel as a "dirty" fuel that is harmful to the environment and the public.

Funding Assistance - The only possible source of assistance would be from an engine manufacturer eager to get their engine into our fleet. Assistance could be in the form of extended warranties, reduced engine pricing, or spare units furnished at no charge.

Training Costs - The only training required on diesel vehicles is related to periodically updated emission control systems. These costs are generally covered by the engine manufacturer.

Fuel Availability - There are numerous qualified, responsive vendors with adequate supplies and delivery capability for our operation.

Fuel Quality - The product furnished by local vendors has been of consistent good quality as evidenced by test results and the lack of fuel related problems.

Fuel Price Stability - Historically, diesel prices have been stable, but are very susceptible to political factors affecting the market.

COMPRESSED NATURAL GAS (CNG)

<u>Vehicle Cost</u> - Vehicle cost is very high for CNG - at least 20% higher than a base diesel bus. Some factors driving this cost are:

- High fuel tank cost and number of tanks per vehicle.
- High cost of low production, dedicated gas engines.
- High vehicle production cost due to added complexity.
- On board methane detection systems.
- On board fire suppression systems.
- Increased product liability costs.
- Increased delivery cost - must be trucked on flat-bed.

<u>Infrastructure Cost</u> - Infrastructure costs are also very high. Some factors are:

- Compressor stations adequate for fast fill can cost 2 to 4 million dollars per station.
- Extensive modifications are required to facility HVAC systems for indoor storage.
- Methane detection systems are required.
- All electrical equipment overhead must be made explosion proof.

<u>Safety</u> - Methane gas is lighter than air and can collect in overhead areas, creating an explosion hazard. Another safety factor is the high pressure that is required for dispensing and storing the fuel - approximately 3600 P.S.I. Sudden releases due to collision damage or equipment failure can be dangerous.

<u>Operating Range</u> - Since methane gas has such a low energy content, a great deal of space must be dedicated to on-board fuel storage to obtain an acceptable operating range. Our existing CNG buses have a 30% lower operating range than our diesel buses, and are much heavier due to the additional fuel tanks.

<u>Operating Cost</u> - There are a number of factors affecting operating costs that are unique to CNG fuel, such as:

- Additional energy costs to operate the fast fill fueling station.
- Maintenance costs for the fueling station. A state of the are facility in Sacramento, CA. requires a stationary engineer inn attendance a minimum of 70 hours per week.

- Insurance costs for vehicles and facilities are higher due to perceived additional risk.

- Vehicle replacement parts costs are higher due to lower production volumes.

- Tire leasing costs are higher due to the heavier weight of the vehicles.

- Repair labor costs are higher due to added complexity and unfamiliarity with technology.

- More frequent replacement of brake and suspension components due to added vehicle weight.

- Downtime per failure is longer due to problems in obtaining fuel system related repair parts.

- Successful fuel cost negotiations require the use of consultants rather than in-house personnel. Natural gas for use as a motor fuel is not regulated by the Public Service Commission.

- CNG engines require a special, more costly lubricating oil.

- Energy costs for HVAC are higher due to the additional air flow required for storing CNG vehicles indoors.

- Due to the weight of CNG vehicles, Federal Regulations may require special operating permits.

Reliability - CNG is a relatively mature technology, but has more frequent failures than diesel vehicles. The spark ignition system and carburetor/regulator fuel system are inherently less reliable than diesel engine systems.

Customer Acceptance - Natural gas is perceived as an environmentally friendly fuel, but some customers have expressed concerns about the safety of the fuel system.

Funding Assistance - The local utility company has expressed willingness to assist in financing the acquisition of new vehicles.

Training Costs - Specialized training is required for mechanics, fuelers, operators, supervisors, and safety and facility maintenance personnel.

Fuel Availability - Natural gas is domestic, abundant, and available at all locations without the need for transport deliveries.

<u>Fuel Quality</u> - Fuel quality is good except in periods of peak demand, such as in the winter months. During peak periods, utility companies often supplement their methane supply with propane and butane, a process known as "peak shaving". While peak shaving has no detrimental effects to residential and non-vehicular users, it can have a disastrous effect on dedicated CNG engines, causing detonation and catastrophic engine failure. We have experience 100% engine failure in our CNG buses in 2 years, with all engine failures directly related to fuel quality.

<u>Fuel Price Stability</u> - Price stability should be good through successful rate negotiations and contract structures.

LIQUEFIED NATURAL GAS (LNG)

Vehicle Cost - LNG vehicle costs are comparable to CNG in all aspects except the number of fuel tanks required. LNG vehicles operate with a single fuel tank due to the fuel being in liquid form. While only one tank is required, that tank is far more costly than a diesel tank.

Infrastructure Cost - Infrastructure costs are comparable to CNG in all aspects except for fuel dispensing equipment. Since the fuel is pumped in liquid from, expensive compression equipment is not required. LNG is however a cryogenic liquid, and the dispensing equipment is highly specialized and expensive.

Safety - LNG, like CNG, has vapors that are lighter than air and collect in overhead areas, causing explosion hazards. Since LNG is a cryogenic liquid, stored and dispensed at -268 degrees Fahrenheit, the effects of spills could be disastrous to anything or anyone in the path of the spill. Unlike CNG, LNG is odorless, and methane sensors are required on vehicles and in facilities.

Operating Range - Since LNG is stored as a liquid, adequate on-board storage for acceptable operating range is achievable without the use of extra tanks.

Operating Cost - There are a number of factors affecting operating costs that are unique to LNG fuel, such as:

- Frequent replacement of expensive dispensing nozzles. Currently, the only nozzles designed for production fueling are used by the Military, and they are replaced after 400 fuelings.
- Insurance costs for vehicles and facilities are higher due to perceived additional risk.
- Vehicle replacement parts are higher due to lower production volumes.
- Repair labor costs are higher due to added complexity and unfamiliarity with technology.
- Downtime per failure is longer due to problems in obtaining fuel system related parts.
- LNG engines require a special, more costly lubricating oil.
- Energy costs for HVAC are higher due to the additional air flow required for storing LNG vehicles indoors.

Reliability - LNG engine reliability is comparable to CNG. An additional problem with LNG is short service life of the on-board cryogenic fuel pump, and poor reliability of the meters on the dispensing pumps. Dispensing errors cause LNG vehicles to run out of fuel while in service frequently.

Customer Acceptance - Same as CNG

Funding Assistance - Some funding assistance may be available from the fuel supplier to help offset engineering costs for the fueling system and the facility modifications.

Training Cost - Specialized training is required for mechanics, fuelers, operators, supervisors, and safety and facility maintenance personnel.

Fuel Availability - Locally, the fuel is not presently available and would have to be trucked approximately 300 miles. Liquid Carbonic, a potential fuel supplier would erect a local cryogenic plant for LNG if we had enough dedicated vehicles.

Fuel Quality - The cryogenic manufacturing process used to make LNG makes it the purest, most consistently high quality fuel of all the alternatives.

Fuel Price Stability - Long term contracts are obtainable to help ensure price stability.

METHANOL

Vehicle Cost - Methanol vehicle costs are very high, comparable to CNG and LNG vehicles. Some factors driving this cost are:

- High fuel tank cost and number of tanks per vehicle.
- High cost of low production, dedicated methanol engines.
- Methanol is extremely corrosive, requiring all fuel system components to be made of more costly, corrosion resistant material such as stainless steel.
- High vehicle production cost due to added complexity.
- On board fire suppression systems.
- Increased product liability costs.
- Increased delivery costs - must be trucked in on flat-bed.

Infrastructure Cost - Infrastructure costs are high due to the following factors:

- A separate dedicated fueling system is required, with special tanks and spill sensors.
- Modifications are required to HVAC system for indoor storage.
- Automatic fire suppression equipment is required in fueling area.
- All electrical fixtures in fueling repair, and storage areas must be explosion proof.

Safety - Methanol is the least safe fuel of all available alternatives, due to the following:

- Vapor is heavier than air.
- Low flash point.
- Invisible flame.
- Extremely toxic.
- High spill risk - completely miscible with ground water.

Operating Range - Methanol has a low energy content, so additional on-board storage is required to obtain an acceptable operating range. This adversely impacts vehicle weight.

Operating Cost - Operating costs overall are no less than double diesel operating costs per figures from RTD in Los Angeles. Some factors are:

- High fuel cost.
- Poor fuel economy.
- Higher insurance costs for vehicles and facilities.
- More frequent preventive maintenance schedule from engine manufacturer.
- Short service life on engines and fuel system components.
- Vehicle replacement part costs are higher due to lower production volumes.
- Tire leasing costs are higher due to the heavier weight of the vehicles.
- More frequent replacement of brake and suspension components due to added vehicle weight.
- Energy costs for HVAC are higher due to additional airflow required for indoor storage.
- Due to vehicle weight, Federal Regulations may require special operating permits.

Reliability - Field test of methanol buses at RTD in Denver and RTD in Los Angeles have shown that engine and fuel system related failures occur not less than twice as often as on diesel vehicles.

Customer Acceptance - Methanol is perceived as an environmentally friendly fuel, but the EPA is currently expressing concerns about formaldehyde emissions. Many customers are wary of vehicle safety with this volatile, toxic fuel.

Funding Assistance - Not available at this time.

Training Costs - Specialized training is required for mechanics, fuelers, operators, supervisors, and safety and facility maintenance personnel.

Fuel Availability - Methanol can be made from natural gas, coal, and wood products, so feedstocks are abundant. Local supply is currently poor, and some methanol is imported.

Fuel Quality - Test fleets have reported no problems related to fuel quality.

Fuel Price Stability - Unknown at this time, but expected to be relative to diesel stability.

ETHANOL

Ethanol is comparable to methanol in every aspect except three:

- Ethanol is less toxic than methanol.
- Ethanol is derived from agricultural feedstock-corn.
- Some funding assistance may be available from ethanol processors or farm cooperatives.

BIODIESEL

Vehicle Cost - Vehicle cost is the same as diesel. No engine or vehicle modifications are required to accommodate the use of biodiesel.

Infrastructure Cost - Again, the same as diesel. No modifications are required to fueling systems or HVAC systems to accommodate biodiesel. No additional spill sensors or safety equipment is required.

Safety - Safety is slightly better than diesel. A 20% biodiesel content in petroleum diesel reduces overall toxicity and raises the flashpoint.

Operating Range - Operating range is the same as diesel, with no additional on-board storage required.

Operating Cost - Operating cost is higher than diesel. This is due solely to the cost of fuel.

Reliability - Reliability is virtually the same as diesel. On road tests of over 200,000 miles had no fuel related failures.

Customer Acceptance - Biodiesel is perceived as environmentally friendly, renewable, and safe.

Funding Assistance - Assistance is possibly available through tax breaks being lobbied for in Congress. The use of biodiesel also tends to show rural voters a direct benefit to them of subsidizing urban mass transit.

Training Costs - No special training is required.

Fuel Availability - Availability to date has been acceptable, but no local vendor has yet been established. There is more than adequate quantity available.

Fuel Quality - Fuel quality to date has been consistently good. No problems related to fuel quality have occurred in our demonstration projects.

Fuel Price Stability - Biodiesel price stability will be susceptible to all the factors that affect agricultural crop prices.

ATTACHMENTS

1. Summary of alternate fuel properties and practices from Transportation Research Board, TCRP Synthesis 1

2. Alternate fuel comparison from Booz-Allen & Hamilton

3. Alternate fuel comparison from SCRTD Survey

4. Methanol analysis from Booz-Allen & Hamilton

5. Capital cost analysis for methanol and CNG from Booz-Allen & Hamilton

6. Article "Is the diesel dead?" by David Merrion, President Detroit Diesel, from Diesel Equipment Specialist

7. EPA and CARE Emission Standards

ATTACHMENT I

TABLE S-1
SUMMARY OF ALTERNATIVE FUEL PROPERTIES AND PRACTICES

	Methanol	Ethanol	CNG	LPG	LNG
Storage	As for conventional fuels	As for conventional fuels	High pressure cylinders (up to 5,000 psi)	Moderate pressure tanks (up to 375 psi)	Cryogenic (-26°F) moderate pressure (up to 150 psi)
Dispensing	As for conventional fuels; positive locking nozzle desirable	As for conventional fuels; positive locking nozzle desirable	Specialized high-pressure fueling connector	Specialized fueling connector	Specialized cryogenic fueling connector
Vapor Recovery	Desirable	Desirable	Not applicable	Desirable	Required
Exposure Hazards	Highly toxic via ingestion, vapor inhalation, or skin contact	Moderately toxic via ingestion	Physical hazard due to high pressure, can cause injury or embolism	Physical hazard due to high pressure, can cause injury or embolism; latent heat of vaporization can freeze tissue	Serious physical hazard due to cryogenic temperature; contact with fuel or equipment cooled by fuel can cause severe frostbite
Fire Hazards	Vapor heavier than air; flame invisible in daylight; ignites more readily than diesel	Vapor heavier than air; flame nearly invisible in daylight; ignites more readily than diesel	Released gas is lighter than air; ignites more readily than diesel	Vapor heavier than air; ignites more readily than diesel	Vapor lighter than air; ignites more readily than diesel
Fire Prevention for Facilities	Ventilation and/or explosion-proof equipment at floor level and in pits	Ventilation and/or explosion-proof equipment at floor level and in pits	Ventilation and/or explosion-proof equipment at ceiling level and in pits	Ventilation and/or explosion-proof equipment at floor level and in pits	Ventilation and/or explosion-proof equipment at ceiling level and in pits; methane detectors desirable as fuel is not odorized
Automatic On-Board Fire Suppression	Desirable	Desirable	Desirable	Desirable	Desirable
Capital Costs	Moderately higher than diesel	Moderately higher than diesel	Significantly higher than diesel	Moderately higher than diesel	Significantly higher than diesel
Operating Costs	Significantly higher than diesel	Significantly higher than diesel	Similar to diesel	Similar to diesel	Similar to diesel
Vehicle Issues	Moderate range and/or weight penalty	Slight-to-moderate range and/or weight penalty	Significant range and/or weight penalty	Slight range and/or weight penalty	Slight range and/or weight penalty

ATTACHMENT III

ALTERNATIVE FUEL COSTS

Cost estimates based on late 1990 survey by SCRTD, and extended to represent a 75 bus purchase.

	Diesel	Trap	Methanol	CNG
CARB Compliance	No	Yes	Yes	Yes
Capital Investment	Baseline	+$1.05M	+$3.6M	+$4.8M
Fuel Cost (12 Yr. Life)	Baseline	+$1.8M	+$16.8M	+$2.5M
Fueling Facility	Baseline	0	+$1M	+$2M
Training	Baseline	None	Substantial	Substantial
Added Maintenance	Baseline	Negligible	Substantial	Substantial
Reduced Passengers	Baseline	0	-5	-19
Bus Test Costs	Baseline	0	+$.4M	+$.4M
Future Viability	Poor	Fair, but transitional	Fair, but transitional	Better, but transitional
Safety Concerns	Baseline	None	Yes	Yes
Health Concerns	Baseline	None	Yes	No
Overall Pollution (includes pollution to produce fuel)	Baseline	Slightly less	Slightly less	Less

3.1.3 <u>Methanol Engine Maintenance</u>

Vehicle maintenance costs are higher for methanol vehicles as compared to diesel due to the more rigorous maintenance schedules being proposed by methanol engine manufacturers. DDC has developed a recommended methanol engine maintenance schedule shown in Exhibit 3-9. The oil and oil filter replacement intervals are the same as for diesel coaches. DDC has however recommended that fuel filter replacement be a little earlier for methanol engines. As the fuel filter mesh is more fine in methanol engines, the first change is especially important. The glow plug and injector replacement schedules are somewhat conservative. As the reliability of these two engine components improves (demonstrated by a dramatic decrease in unscheduled maintenance), the replacement schedule may become less aggressive.

EXHIBIT 3-9

Methanol Bus Engine Maintenance Requirements

COMPONENT	SCHEDULE		
	MILES	OR	MONTHS
GLOW PLUGS - REPLACE	50K		12
INJECTORS			
- CLEAN TIPS	50K		12
- CHANGE OUT (1)	100K		24
BYPASS CONTROL COMPONENTS			
- PWM SOLENOID VALVE - REPLACE	50K		12
- FEEDBACK POTENTIOMETER - REPLACE	100K		24
- AIR PRESSURE REGULATOR FILTER - CLEAN	Per Manufacturer's Recommendation (3)		
CHANGE OIL & FILTER (2)	6,000		—
CHANGE FUEL FILTERS			
- 1st CHANGE	1,000		—
- THEREAFTER	6,000		—

(1) A remanufacturing exchange program will be established.
(2) Oil leak must be changed if contaminated with fuel from injector leak.
(3) This component is supplied by the bus manufacturer.

3.1.4 **<u>Methanol Safety Issues</u>**

Fuel safety issues have been a major concern with methanol for use as a motor vehicle fuel. Safety issues for methanol focus on:

- Toxicity
- Leak Detection
- Maintenance Procedures
- Flammability Limits
- Vapor Inhalation.

Methanol is highly toxic and, unlike petroleum products, can be absorbed through the skin. Chronic exposure to methanol above 200 ppm has produced symptoms of methanol toxicity such as dizziness, headaches, nausea and blurred vision. A recent review of methanol health effects completed by the Health Effects Institute in 1987 indicated that continued exposure to low levels of methanol may result in effects similar to those caused by acute exposure. Exhibit 3-10 provides an estimate of the tolerance levels for methanol.

EXHIBIT 3-10

Estimated Tolerance Levels for Methanol (1)

EXPOSURE DURATION	TOLERANCE LEVEL (ppm)
Single Exposure	
1 hour	1,000
8 hours	500
24 hours	200
40 hours (1)	200
168 hours	50
30 days	10
60 days	5
90 days	3
Repeated Exposure	
1 hour/day	500
2 hours/day (2)	200

(1) Based on five 8-hour working days.
(2) Either two 1-hour exposures or one 2-hour exposure per day.

In ventilated areas, the ignitability of neat methanol is between those of gasoline and diesel fuel. In enclosed spaces, nest methanol is flammable over a wide temperature range.

Relative to gasoline or diesel fires, methanol fires are more controlled and burn cooler because of its lower heat of combustion and higher heat of vaporization. However, a major problem is that methanol fires are invisible in daylight.

Existing fire prevention codes and recommendations include precautions to maintain the storage temperature below the flammability range and limit ignition sources near the fuel. In addition, desirable fire extinguishers include dry chemicals, carbon dioxide or alcohol-resistant foam concentrates.

ATTACHMENT V

Last, the ECS Catalyzed Trap Oxidizer System being tested at SEPTA differs from the other trap systems in that it is passive. In other words, regeneration is not initiated by any external heat source such as diesel or electric heaters. The catalyst on the filter element works with the heat in the exhaust to regenerate the trap when the exhaust temperature exceeds a threshold value.

The advantage of this trap technology is the elimination of control equipment required by other systems. A typical externally heated trap system includes a heat source, blower and system controller, and sensors to monitor the trap system and initiate regeneration. Particulates may be reduced by as much as 90 percent with the ECS Catalyzed Trap Oxidizer.

The primary concern with all of these trap systems is the long-term durability of ceramic filters. Regeneration takes place at temperatures in excess of 1100 degrees Fahrenheit. At this high temperature, the ceramic elements are susceptible to cracking.

3.4 ALTERNATIVE FUEL CAPITAL VEHICLE COSTS

This section discusses the differences in vehicle capital costs for each clean engine alternative.

3.4.1 Methanol Vehicle Costs

A study conducted by New Jersey Transit concluded that methanol buses will cost an estimated 22 percent more than diesel buses. Given that conventional diesel coaches cost approximately $175,000 methanol coaches will cost a little under $215,000. The difference of $40,000 is due to the required fuel and engine system modifications. These modifications include:

- Methanol Engine. DDC plans to offer their 6V-92 methanol engine, January 1, 1991. A formaldehyde catalyst will become available approximately two months later. At present DDC has orders for 200 units and estimates the cost for the engine/converter to be approximately twice today's diesel engine (≈35,000).

- Fuel Delivery System. A new fuel system encompasses an additional fuel tank, new fuel filters, new fuel lines, new electric fuel pump and a fuel cooler. Special methanol compatible fittings are required throughout. Pressure relief valves and flame arrestors are also required on both tanks. Diesel engine coaches already require some of these fuel system components (filters and lines). For methanol operation, the material and design will differ. Therefore, the additional cost incurred for the fuel delivery system will be for installation of a secondary fuel tank, a fuel cooler and replacement of the current mechanical pump with an electric pump.

- Fire Suppression System. As methanol is more volatile than diesel fuel, its recommended the vehicle be equipped with a fire protection system which includes fuel tank protection.

As shown in Exhibit 3-20, the engine accounts for roughly 90 percent of the higher vehicle costs.

EXHIBIT 3-20
Methanol Coach Vehicle Capital Costs

3.4.2 <u>CNG Vehicle Costs</u>

The major cost items for CNG vehicles are the engine, on-board fuel storage systems, fire protection system, on-board fuel delivery system and required vehicle structural modifications. For the city of El Paso, Texas, Flxible submitted a CNG vehicle bid price of $285,000. (Note: The El Paso bid was a 79-bus order with a scheduled delivery date in the second quarter in 1991 and included line options for up to 5 vehicles which operate on either methanol or CNG.)

The natural gas engine cost does not account for as large a percentage of the price increase as compared to methanol. Cummins plans to sell CNG L-10 engines equipped with catalytic converters commencing January 1, 1991. Orders are currently in place for 300 to 400 units. The engine/catalyst is estimated to cost approximately 2 times what today's diesel engine costs (~$35,000).

DDC`s dual fuel CNG engine will also become available January 1, 1991 and the engine manufacturer plans to produce 100 units. Purchasers will have the option of replacing this engine with the 100 percent CNG pilot engine which is scheduled to become available in mid-1991. DDC has not estimated the costs of wither version of their CNG engine at this time.

CNG fuel storage tanks which are presently commercially available have a unit cost of $2,500 to $3,000 over the price of a single 125-gallon tank. The Flxible CNG bus requires six 19-inch diameter 78.5-inch long storage tanks at a total estimated cost of $21,000.

We estimated the fire protection system to cost $3,000 for the methanol coach and have assumed the price will be the same for the CNG vehicle application.

CNG on-board fueling system components include the manifold, shut-off valves, pressure relief devices, pressure regulators, pressure gauges and piping and hoses.

Fuel system modifications also include installation of a venting system (pressure relief device channels). The National Fire Protection Association has developed specific guidelines for natural gas vehicle venting systems as follows:

- The tanks shall not exit into a wheelwell.
- A vent shall not restrict the operation of a tank pressure relief device.
- The venting system shall be constructed of metallic tubing with threaded, compression or flare fittings.

In addition, the vehicle structure may require additional support members in order to satisfy guidelines which exist in regard to structural deflection and load carrying capabilities.

Based on the El Paso bid price, fueling system and vehicle modifications account for approximately $51,000 of the CNG vehicle costs. However, we feel this figure is somewhat high and reflects some of the vehicle re-engineering which Flxible would have to perform for the El Paso demonstration. Actual CNG production vehicle costs will most likely be significantly lower. Exhibit 3-21 shows the breakdown of CNG vehicle component systems costs.

EXHIBIT 3-21
CNG Vehicle Cost Breakdown

ATTACHMENT VI

SOUNDING *BOARD*

Is The Diesel Dead?

By David Merrion

Recently, it appears that the diesel engine industry has come under increasing fire from governmental agencies. Considering some of their actions, it seems they would like to see the diesel die.

Heavy-duty engines, defined by the U.S. Environmental Protection Agency (EPA) as engines in vehicles over 8,500 lbs GVWR, have been emissions regulated since 1974. The EPA requires the use of an engine dynamometer test procedure, rather than the vehicle test used in light-duty testing. The 1990 Clean Air Act defined future emissions regulations for heavy-duty trucks and urban buses for the years 1991, 1994 and 1998 covering oxides of nitrogen (NOx), hydrocarbons (HC), carbon monoxide (CO) and particulates (PM).

At the same time that more stringent emissions standards were being implemented, fleets were demanding better fuel economy and performance from their engines. The diesel engine industry has made a 70% reduction in NOx emissions over 20 years, while significantly improving the fuel economy of heavy-duty trucks. This is particularly significant since NOx reduction is accomplished in a diesel engine by making combustion poorer, so fuel economy usually suffers.

Diesel engine thermal efficiency also continues to increase (over 40%) which leads to good fuel economy and low CO emissions. The improvement in fuel economy has been achieved without CAFÉ standards and , of course, the CO results in less greenhouse gases.

In anticipation of future rigorous emissions standards for heavy-duty engines, Detroit diesel and other manufacturers have developed a new generation of electronically controlled engines. Turbocharging and air-to-air charge cooling also allow engines to achieve the lowest intake air temperature possible for good fuel economy and low NOx emissions. In addition, by customizing the variable timing feature with electronic software, engines can achieve excellent fuel economy while readily meeting required exhaust emissions standards.

Meeting the 1994 particulate emissions standard of 0.10 g/hp-hr, on the other hand, is a more difficult task. Studies by the Coordinating Research Council have been investigating the effect of clean diesel fuels, some of which contain increased levels of oxygen, on emissions. Here's an example of what can be done with higher oxygenated fuels. In hot transient testing, using 1994 certified fuel, particulate matter was reduced slightly while NOx remained the same. When super premium light diesel fuel was tested, both particulates and NOx were substantially reduced. The more oxygen, the lower the particulate level.

There is a great deal of discussion going on about reformulated gasoline and reformulated diesel fuel. Although we're not sure what reformulated diesel fuel will turn out to be, it will have qualities other than just a low sulfur content. It's interesting to note that while reformulated gasoline has been accepted as an alternate fuel, reformulated diesel has not.

Air pollution can be reduced significantly by improvements in diesel fuel quality because they would result in:

- reduced emissions from all diesel engines - not just future engines,

• emissions reductions beyond those obtainable with engine hardware changes,
• additional engine changes to provide emissions reductions which would not otherwise be practical..

The U.S. needs a cost effective diesel fuel of improved quality to reduce exhaust emissions. Additional test work and cooperation between engine manufacturers and fuel producers is necessary to develop the specifications for an improved diesel fuel with a maximum cost-to-benefit ratio. The Engine Manufacturers Association has made diesel fuel quality recommendations to the American Petroleum Institute for 1994.

Although reformulated diesel fuel can result in lower emissions, it may not be able to reduce emissions low enough to meet future standards, and it doesn't help with U.S. energy security. In order to meet U.S. energy and environmental goals, alternative fuels provide opportunities.

The alternative fuels we know today are methanol, ethanol, CNG and LNG. Research into and development of alternatives to diesel-powered engines are ongoing. Since the mid-1970s, Detroit Diesel Corporation and other OEMs have been developing engines capable of operating on a variety of alternate fuels. Developments to date include:

• **Methanol.** Trucks have been in operation in California for the last two years. This fuel may be ideal for certain niche trucking applications, such as refuse packers or street sweepers. There are a number of other demonstration methanol truck applications as well.
• **Ethanol.** We expect to see ethanol-powered engines certifies sometime this fall. Trucks powered by E-95, a blend of 95% ethanol and 5% gasoline, are in day-to-day operation at the Archer Daniels Midland fleet.
• **CNG.** Compressed natural gas fuel tanks require a large amount of space. Buses obviously have more space to place the tanks than over-the-road trucks and therefore may be an appropriate application for CNG.
• **LNG.** Liguefied natural gas has all the advantages of CNG without the major drawback of using valuable cargo space to haul fuel. It may be a better choice for the freight transportation industry, and LNG may be a better option for over-the-road vehicles.

Diesel engines can be converted to burn natural gas and provide low emissions and good fuel efficiency. However, there are concerns with natural gas as an automotive fuel, just as there are with methanol and ethanol. These include working out the extra space and weight requirements to carry CNG tanks, extra time to fuel vehicles and the complexity and expense of constructing a natural gas infrastructure.

The U.S. Clean Air Act Amendment of 1990 set emissions standards through 1998 for truck applications. The CAAA requires a four-year lead time, meaning that the next set of standards which could by implemented would be targeted for 2002.

The population of heavy-duty trucks is small in comparison to automobiles and light-duty trucks, but the vehicle miles travelled greatly raises heavy-duty trucks' contribution to petroleum consumption. Heavy-duty vehicles would be expected to make their contribution to reducing the usage of petroleum. This could require a percentage of heavy-duty vehicles, based on either fuel consumed or vehicle miles travelled, to be alternatively fueled.

Congress is putting the last minute touches on the National Energy Strategy. Both the Senate and House bills have passed and are in conference now. Both bills mandate that certain percentages of centrally fueled fleets must have alternatively fueled vehicles in operation by specific dates in cities with populations over 250,000 people. The bills cover only trucks weighing up to 26,000 lbs.

For the past three years, I have participated in the President's U.S. Alternate Fuels Council, whose members represent a diversity of transportation, fuel and environmental concerns. The council's recommendations include a goal that 255 of the miles travelled by vehicles by the year 2010 must be alternatively fueled by non-petroleum products.

Is the diesel dead? No. Looking into the year 2000, diesel engines will continue to provide the power for trucks. Clean diesel will be available, and diesel engines will still be the most fuel-efficient power. Diesel engine manufacturers have done a good job in meeting both energy and emissions requirements. And they will continue to do so.

ATTACHMENT VII

EPA & CARB - Emissions Standards

Heavy-Heavy Duty Diesel Engines

Urban Transit Buses

Model Yr.	NOx	HC	CO	PM
1988 E/C	10.7	1.3	15.5	.60
1990 E/C	6.0	1.3	15.5	.60
1991 E	5.0	1.3	15.5	.25
1991 C	5.0	1.3	15.5	.10
1993 E/C	5.0	1.3	15.5	.10
1994 E/C	5.0	1.3	15.5	.05
*1996 C	2.5	1.3	15.5	.05
1998 E/C	4.0	1.3	15.5	.05

Heavy Duty Trucks

Model Yr.	NOx	HC	CO	PM
1988 E/C	10.7	1.3	15.5	.60
1990 E/C	6.0	1.3	15.5	.60
1991 E/C	5.0	1.3	15.5	.25
1994 E/C	5.0	1.3	15.5	.10
1998 E/C	4.0	1.3	15.5	.10

E/C = EPA & CARB
E = EPA only
C = CARB only
*Proposed CARB-Urban Transit Bus Std. For ’96 which would preempt ’98 CARB Std.

Note: All emissions levels in grams/BHP/HR.