# Connecticut Department of Transportation
# Evaluation of Alternative Fuel Light Trucks and Automobiles

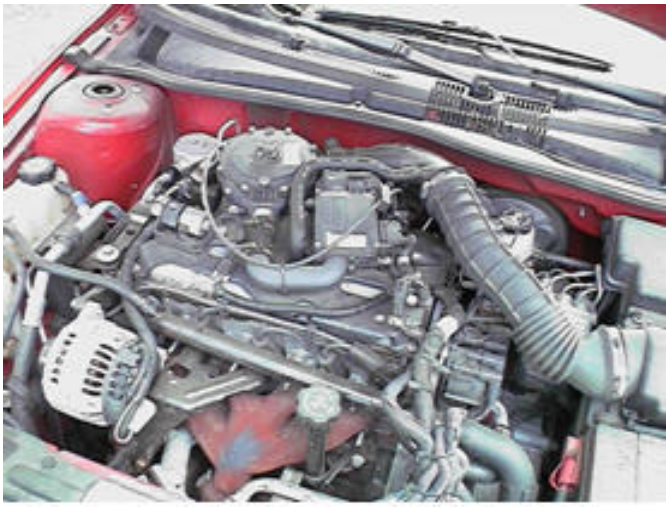
The goal of the project was to gather first- and second-hand data and information about the performance of alternative fuel (ALT-Fuel) light trucks and automobiles; analyze and synthesize the materials; and, develop findings to aid State and Federal officials in their planning for future government fleets to comply with Section 507(o), the Energy Policy and Conservation Act of 1992 (EPACT).

## Background

In 2005, the State fleet consisted of 4,041 passenger vehicles. The Department of Transportation (DOT) was assigned 221 of these vehicles. In addition, the DOT owned and operated 2,099 specialty vehicles (528 buses, 713 dump trucks, 344 pickups, etc.). Both DAS and DOT must comply with EPACT requirements to purchase specified minimum percentages of cars and light trucks that operate on fuels other than gasoline or diesel fuel. EPACT excludes emergency vehicles from these requirements. Compliance with EPACT strengthens US energy security by reducing dependency on foreign oil. In 1996, DOE regulations were modified, but the basic goals remained intact. In 1998, DAS purchased 70 dual-fuel compressed natural gas (CNG)/gasoline sedans that met the federal 15% fleet-purchase requirement. In 1999 and 2000, larger purchases were carried out to comply with 25% and 50% fleet-purchase requirements. After 2000, flex-fuel vehicles were purchased to meet EPACT requirements. In 2000, the national consumption of alternative fuels was 0.2% of total transportation fuels in the US. CNG represented 29.5% of all alternative fuels in the US.

In 1998, the Department initiated research project SPR-2223, titled “Evaluation of Alternative Fuel Light Trucks and Automobiles,” to gather field data and performance information on vehicles operated in Connecticut that are powered from electricity and CNG, to assist both State and Federal Officials with information about these options, which could be used to comply with the Energy Policy and Conservation Act of 1992, Section 507(o).

## Compressed Natural Gas (CNG) Vehicle



**Compressed Natural Gas (CNG) Vehicle Bi-Fuel System**

A 1998 Chevy Cavalier Sedan, bi-fuel compressed natural gas vehicle, that was part of the state fleet, was selected for evaluation. It was operated under various weather conditions, trip lengths, and fuel types to document the performance, practicality, and limitations of operating this type of vehicle in Connecticut. From November 1998 to May 2003, the Research staff accumulated 27,000 miles on the subject vehicle. Forty percent of the weekly mileage driven was well within the CNG tank capacity range. If the CNG tank was fueled prior to each individual trip, 90 percent of all trips recorded in the 55-month time frame were within the range of the CNG-tank's capacity. A majority of the trips taken were less than 30 miles in length. Overall CNG fuel economy was 25.6 MPG. The automobile manufacturer made several changes to the standard Chevy Cavalier (reduction in both trunk and fuel tank sizes) to equip this vehicle with the bi-fuel system and improve its fuel efficiency over the years. Production of the bi-fuel Chevy Cavalier was discontinued after the 2004 model year.

Based on data gathered during this evaluation period, November 1998 to May 2003, the following observations were made:

1. The benefits of powering a bi-fuel vehicle with natural gas in the State fleet have not been fully realized in Connecticut due to several factors:
   a. For employees, a lack of familiarity with CNG fueling may have discouraged usage of the vehicle by staff (less than 490 miles per month).
   b. Lack of conveniently located CNG refueling facilities in Connecticut discouraged CNG refueling.
   c. The fact that it was possible to operate the Chevy Cavalier exclusively on gasoline discouraged CNG refueling.
   d. Lack of meaningful price differential between CNG and gasoline in Connecticut discouraged CNG refueling.
   e. Under EPACT 1992, State Fleets are not required to report ALT-Fuel usage, i.e., displacement of gasoline. The Act only requires equipment purchases.

2. There is limited trunk cargo space provided in the bi-fuel CNG Chevy Cavalier. Comparing the manufacturer's specifications of the bi-fueled Cavalier's trunk space to the standard Cavalier's cargo space, approximately half the cargo room was eliminated due to placement of the CNG storage tank and spare tire.
3. The actual amount of CNG-tank capacity is influenced by three factors: station's fuel pump pressure, station's fuel-pumping speed and ambient air temperature at time of fueling.
4. The CNG refilling station in Hartford did a good job of compensating for differences in ambient temperature. We observed that a 25°F rise in ambient temperature resulted in less than a two percent reduction in CNG tank capacity.
5. There was some driver confusion because the same fuel gage scale is utilized for both tanks: 6-gallon CNG and 15-gallon gasoline tanks. Also, it was difficult for a driver to estimate the number of miles which can be driven on a full tank of CNG.
6. With only one fuel gage, drivers complained about the initial experience involving the fuel switchover process. During the fuel change, there were several miles in which the fuel gage would indicate the CNG tank is empty, but the engine would continued to function. This period of time until the gage reading switched to the other fuel (gasoline) was unnerving to some drivers. One question that came to mind when operating the vehicle in this gray zone was whether there was any gasoline in the other tank. Drivers generally didn't read the manual and discover that a button on the dash could be pressed that would display the fuel level in the 'other' tank.
7. CNG fuel economy of the study vehicle was on average 17.3 miles per gallon in the city and 29.8 miles per gallon on highways. The vehicle's range on CNG was from 75 to 81 miles in the city and 113 to 143 miles while traveling on the highway.
8. There is a limited number of CNG refueling stations in Connecticut. Only two CNG stations are available to the public operating within a 70 mile radius of the Rocky Hill Research Facility (Cities of Hartford and Norwalk).
9. After the 2004 model year, Chevrolet stopped manufacturing the Bi-Fueled Chevy Cavalier.

In conclusion, the bi-fuel CNG Chevy Cavalier did function as described by the automobile manufacturer's literature. The bi-fuel capability of this vehicle worked well and provided a means of operating fleet automobiles on an alternative fuel. However, the limited CNG supply infrastructure in Connecticut, together with no requirement to report the amount of CNG fuel consumed by fleet operations and the lack of price-differential incentives between the two fuels in Connecticut limited the acceptance of CNG vehicles in the State Fleet.

## Nickel Cadmium (NiCd) Battery-Electric Vehicle (BEV)

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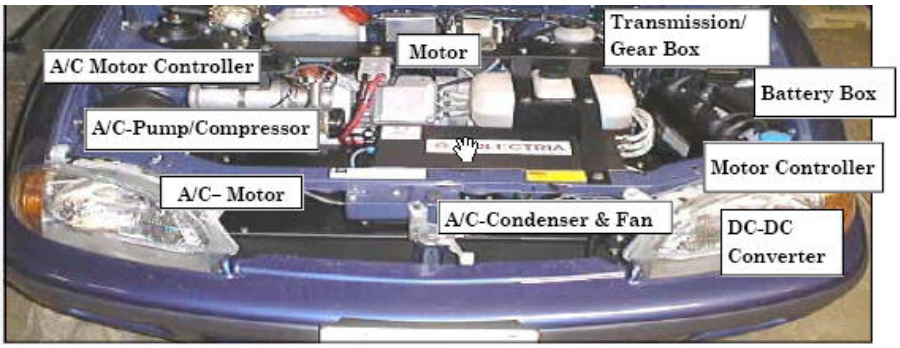


**Under the Hood of a Battery-Electric Vehicle (BEV)**

ConnDOT and The Rideshare Company (Rideshare) previously partnered to evaluate electric subcompact cars that utilized lead acid batteries. Nickel cadmium (NiCd) batteries, popular in European electric vehicles, were anticipated to provide longer and more reliable service. The accuracy of marketing claims of battery electric vehicle (BEV) and battery manufacturers was uncertain.

There was a need to obtain and disseminate some first-hand information about the practicality of this Alt-Fuel option. ConnDOT partnered with Rideshare to retrofit three subcompact BEVs with nickel-cadmium (NiCd) batteries to conduct the two-phase study. The vehicles used were 1995 General Motors Geo Metro(s) retrofitted by the Solectria Corporation. For Phase 2, thin-film photovoltaic laminates were integrated in the NiCd BEVs in order to provide power to offset the small power losses experienced while parked and unplugged.

The study accumulated data from more than 550 individual trips, spanning a distance of nearly 35,000 miles over an eight year period. While researchers were able to attain the 70 mile range in Phase 1, they were unable to replicate the results in Phase 2, as the nominal range of the retrofitted vehicles was approximately 57 miles. In Phase 1, the NiCd pack consisted of 26 six-volt batteries (pack capacity is 15,600 Watt-hours) and had a battery-pack replacement value in 1999 of $8,450. In Phase 2, battery pack capacity was increased to 16,800 Watt-hours (28 batteries). A favorable cost-per-mile statistic for battery-replacement was possible in Connecticut if the NiCd batteries were as long-lived as was claimed by its manufacturer.

The objective was to conduct an evaluation of a Nickel Cadmium (NiCd) battery-electric vehicle (BEV) provided by The Connecticut Rideshare Company (Rideshare). The hypothesis to be evaluated was that a NiCd-powered BEV subcompact with fuel-fired heater/defroster would provide a year-round minimum 70-mile range in Connecticut, would be reliable, and would operate for six years on one battery pack, providing more than 65,000 miles of service before the battery pack needed replacement. In a small state the size of Connecticut (50 miles from north to south and 100 miles from east to west), a 70-mile range was anticipated to be capable of meeting 20 to 30 percent of the fleet’s daily driving needs.

At low ambient temperatures, a NiCd battery was not anticipated to suffer much loss in efficiency; however, the range in winter was anticipated to be slightly less than its range in the other three seasons due to the greater use of accessories (battery pack warmers, passenger electric seat warmers, fuel-fired heater/defroster, electric rear-window defroster, windshield wipers, and headlights). That said, the hypothetical seasonal driving ranges of the NiCd BEV were all anticipated to exceed 70 miles on a battery charge.

The following findings and conclusions were made:

1. A year-round minimum 70-mile nominal (at 70% DOD) range capability was demonstrated for the Phase 1 NiCd-powered BEV via a 30,000-mile evaluation, and longer ranges were attained at greater DODs. A range of over 100-miles was attained on seven occasions and a 120-mile plus range was attained on two occasions.
2. In Phase 2, with three cars under evaluation (car licenses: EV-1, EV-3 and EV-5), the nominal 70% DOD range of the NiCd BEVs dropped to approximately 57 miles for EV-1, 57.9 miles for EV-3 and 24.3 miles for EV-5; which suggests the hand-retrofitted vehicles were not identical.
3. A certain inherent energy loss was observed in EV-5 of approximately 1.5 Wh per minute. A loss of this extent was not observed in EV-1 or EV-3.
4. During Phase 1, in addition to normal maintenance, such as tire rotation, only simple battery maintenance was needed, which included the addition of less than two gallons of distilled water every 3,500 miles.
5. During Phase 2, the three hand-retrofitted battery-electric subcompact cars experienced substantially more problems, including: limited driving range, poor overall reliability, battery self discharge when sitting idle, sudden voltage drops, no photovoltaic kWh data captured by data acquisition system, and an electric powertrain direct-drive unit failure.
6. The BEVs performed better when driven on a routine basis and charged at night with their NiCd batteries frequently cycled, helping to maintain consistent DOD and drive ranges. Infrequent use resulted in reduced drive ranges and lower DODs.
7. In Phase 2, a design change made dual use of the car’s air-conditioning system for passenger cabin cooling and battery-pack cooling. This design worked well and made it possible to charge the batteries at any time, whereas the original EV design wouldn’t initiate recharge any time ambient air temperatures was above 80 degrees Fahrenheit.