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PROJECT SUMMARY

Project Title:	A Preliminary Assessment of the Impact of Flywheel Energy Storage Technology on Taxicab Fleet Operation in a Large Metropolitan City
Principal Investigator:	Milton C. Krupka
Organization:	Los Alamos National Laboratory Analysis and Assessment Division Los Alamos, New Mexico 87545
Project Goals:	Evaluate the impact and benefits in terms of energy conservation, environmental improvement, and economics of incorporating flywheel energy storage systems into fleet vehicle operations. Specifically examine the case of taxicab fleet operations within New York City. Identify institutional barriers to implementation.
Project Status:	The project has been completed and the final report issued, LA-8722-MS, February 1981. Operational information for the study has been obtained from both regulatory and private organizations in New York City. Energy conservation, environmental, and economic impacts have been determined based on assumptions keyed to both operational data and a projected fuel economy for hybrid flywheel-internal combustion engine vehicles.
Contract Number:	LLNL order SANL 620-020, Task 7.203
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ASSESSMENT OF TAXICAB FLEET OPERATION IN NEW YORK CITY

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ABSTRACT

This paper describes a preliminary assessment of the impacts resulting from incorporation of flywheel energy storage systems into automotive fleets in a large metropolitan city. Specifically, the case of taxicab fleet operation within New York City is examined.

Based upon available taxicab operational data, a levelized life-cycle cost comparison between a standard internal combustion engine vehicle in present use as a taxicab and a projected hybrid flywheel-internal combustion engine vehicle (taxicab) has been generated. Energy conservation and environmental benefits are discussed and potential institutional barriers to rapid deployment of flywheel energy storage systems are identified.

The results obtained from this study generally emphasize the value of incorporating flywheel energy storage systems into future vehicles designed for taxicab use.

INTRODUCTION

The incorporation of flywheel energy storage systems (FESS) into automotive vehicles has been under consideration for some time. Previous studies have suggested that FESS can yield substantial benefits in automotive vehicle operation, particularly for urban driving. Enhanced interest has come about due to major advancements in materials science and engineering as applied to flywheel system development.

This study presents a preliminary assessment and evaluation of the economic, energy conservation, and environmental benefits of the introduction of FESS into a standard internal combustion engine vehicle (ICEV). To further assess the impacts resulting from FESS incorporation into certain types of automotive fleets, a preliminary examination of taxicab fleet operation in a large metropolitan city, in particular New York City, was made. The taxicab transportation sector was chosen in view of certain unique operational characteristics that permit a more visible intercomparison of their vehicles with and without new energy storage systems.

AUTOMOTIVE FLEET VEHICLE MARKET AND TAXICAB SECTOR

The fleet market is especially valuable as a technological test market for new vehicle and component design because:

(a) availability of professional management and fiscal resources permits a higher degree of risk involvement;
(b) conscientious maintenance, vehicle control, and record-keeping practices exist;
(c) vehicles can be assigned to specific and well-defined missions;
(d) mileage and operational data accumulate rapidly; and
(e) there is high product visibility.

Because of the wide diversity of purpose existing within the fleet market, it is convenient to subdivide fleets into a number of sectors, one of which is the taxicab sector. In considering the purchase of vehicles within this sector, surveys have indicated that maintenance represents the primary purchase criterion with life-cycle costs and reliability close secondary criteria.

NEW YORK CITY TAXICAB OPERATION*

Characterization of taxicab operation in New York City is difficult because there are several taxi systems. The city has about 12 000 licensed taxicabs, controlled by the New York City Taxi and

*Information mainly obtained from the New York City Taxi and Limousine Commission, 67 Wall St., New York City, New York 10005, and the Metropolitan Taxicab Board of Trade, Inc., 24-16 Bridge Plaza South, Long Island City, New York 11101. The latter organization controls the fleet operation of about 2200 taxicabs, about 20% of those licensed.

Limousine Commission. About 60% operate as fleets and minifleets and the remainder as independent owner/drivers. There is also a substantial but indeterminate number of livery service vehicles (gypsies) operating within and without the city limits and not controlled by the Commission.

Characteristics unique to the New York City taxicab sector include: very high annual mileage accumulation (50 000-80 000 miles); relatively short vehicle lifetime (18-36 months); urban stop-go driving and significant braking; low average speed (about 7-11 mph) and low average gasoline mileage (about 10 mpg) in central business districts (CBD). Additional characteristics, operating parameters, and data used for the economic analysis is given in Ref. 1.

The characteristics of New York City taxicab operation strongly suggest that evaluations of new technologies such as FESS be conducted under New York City taxicab drive cycles in addition to the Federal urban drive cycle usually considered. The former emphasize CBD type of driving and are perhaps best characterized by extensive periods of zero velocity (engine idle or stop) and net low average speeds.

ECONOMIC ANALYSIS

A levelized life-cycle cost (LLC) methodology was used to perform the economic analysis. The advantage of LLC is that the total operating cost, including the capital investment, is characterized by a single number. A detailed discussion of LLC methodology is contained in the user's manual for the computer code (BICYCLE) used in this analysis (Ref. 2). The data used in the analysis reflect primarily that relating to fleet operation with estimates made where necessary.

Results of the analysis are shown in Fig. 1.

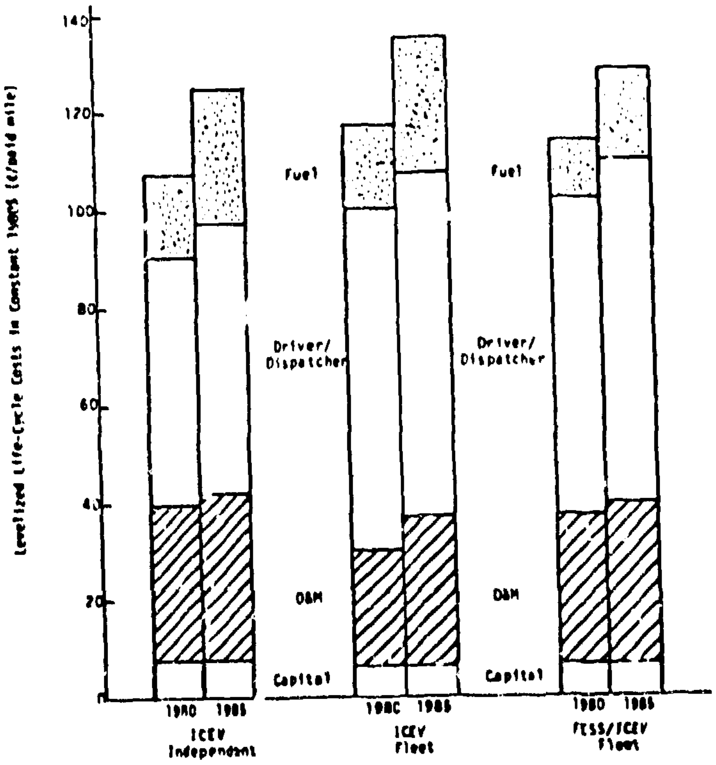

Fig. 1. Comparison of levelized life-cycle costs for three systems of taxicab operation.

Sensitivity studies were performed on selected parameters of interest. Results are shown in Figures 2-4.

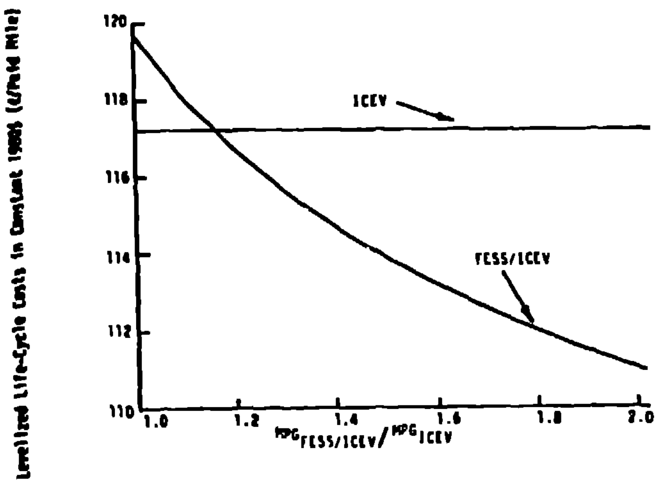

Fig. 2. Life-cycle costs (fleet operation) of taxicab ICEV and FESS/ICEV as a function of fuel economy ratio.

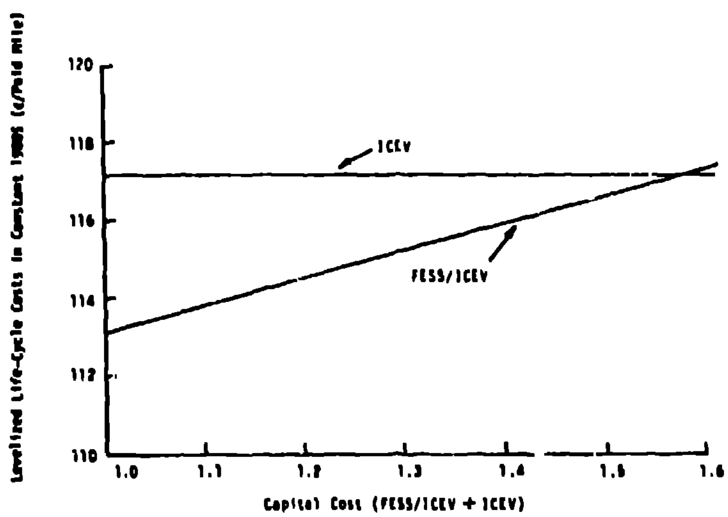

Fig. 3. Life-cycle costs (fleet operation) of taxicab ICEV and FESS/ICEV as a function of capital cost ratio.

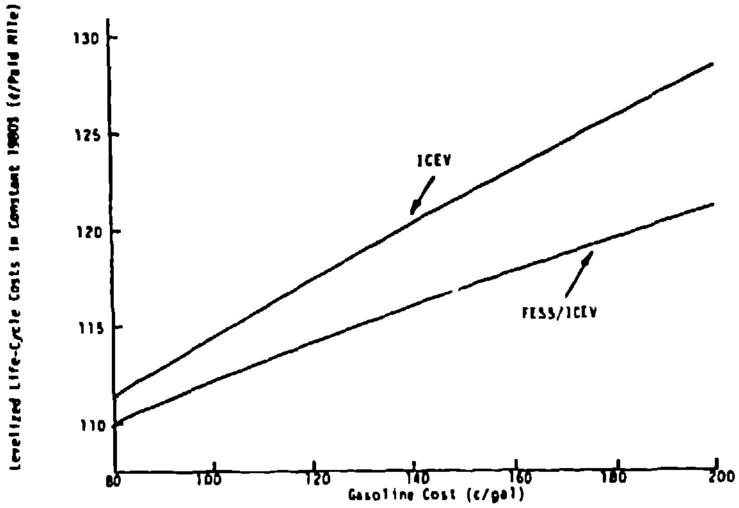

Fig. 4. Life-cycle costs (fleet operation) of taxicab ICEV and FESS/ICEV as a function of gasoline cost.

Life-cycle costs of FESS/ICEV are reduced with continued improvement in fuel economy relative to a base value 10 mpg (1.0 ratio) for the ICEV. The breakeven gasoline mileage is about 11.8 mpg. Operating costs are higher for FESS/ICEV above the breakeven point.

The life-cycle cost vs the capital cost ratio is of particular interest. It suggests that the capital costs for a FESS/ICEV could be increased as much as 58% before exceeding the ICEV life-cycle costs. This additional capital investment would be warranted to achieve projected gains in fuel economy.

The FESS/ICEV system is less costly at all values of gasoline cost shown in Fig. 4. An interpolation would demonstrate breakeven cost at about 60-65¢/gal in this study. As fuel costs increase, the FESS/ICEV becomes progessively more economical.

ENERGY CONSERVATION

The gain in fuel economy projected to come from FESS in a vehicular application is the result of not only the regenerative braking concept but also the concurrent efficient operation of an optimized engine and drive train system. This combined engineered system has been studied by several groups, including the University of Wisconsin, for a number of years (Ref. 3).

As a conservative measure, it is assumed that a 50% gain in fuel economy is realistic for vehicles in the approximate weight class of taxicabs. The savings in energy consumption by licensed taxicabs can be shown assuming the gain mentioned above. For about 12 000 taxicabs accumulating between 50 000-80 000 miles per year, the gain in fuel economy results in a savings of about 33% in fuel purchases, a savings of about 25 x 10^6 gallons per year, which at a cost of $1.20 per gallon amounts to $30 x 10^6 per year. The energy equivalent of gasoline is about 125 000 Btu per gallon, therefore, about 3.1 x10^{12} Btu per year can be conserved.

ENVIRONMENTAL CONSIDERATIONS

The introduction of flywheel technology is likely to have its most noticeable effects upon air quality (emissions) and associated health impacts, especially in urban environments.

The New York City Taxicab and Limousine Commission mandates strict emission standards. Taxicabs of years 1979 and 1980 and the future must meet emission standards equivalent to those for California.

Since there are significant savings in terms of fuel usage, environmental improvement in the form of reduced emissions is to be expected with the introduction of FESS/ICEV taxicabs.

Because New York City also regulates noise levels, any noise problems presently encountered in development should be solved before introduction into the city environment.

INSTITUTIONAL BARRIERS

A number of institutional factors that may visibly affect rapid deployment of FESS/ICEV vehicles in the taxicab market sector have been identified.

These include: the automobile industry production infrastructure as it relates to the small market for taxis; lack of maintenance and service information for the taxicab industry, which prefers relatively short downtime periods; the ownership of patent or commercial rights relating to component development by contractors using government funds; and the necessary education of regulators, insurers, and the public with regard to the safety of FESS. More positively, there is already a precedent in New York City regarding taxicab fleet technology demonstrations, diesel engine-powered taxicabs having been tested previously. Generally, regulations do not appear to be restrictive.

CONCLUSIONS

A preliminary assessment of the economic, energy conservation, and environmental impacts related to the introduction of flywheel energy storge systems (FESS) into automotive (taxicab) fleets in a large metropolitan city (New York City) has been made. The results obtained generally emphasize the value of incorporating flywheel energy storage systems into future vehicles designed for taxicab use. A large-scale demonstration test would provide a more accurate evaluation of the benefits discussed herein.

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