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Driver Energy Conservation Awareness Training: Review and Recommendations for a National Program

David L. Greene

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Energy Division

DRIVER ENERGY CONSERVATION AWARENESS TRAINING: REVIEW AND RECOMMENDATIONS FOR A NATIONAL PROGRAM

David L. Greene

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ABSTRACT

The idea of driver energy conservation awareness was formalized as a training program (DECAT) by the Department of Energy in the late 1970's. This report reviews the curriculum of that program, its basis in engineering tests and principles, its past activities and achievements, and its potential, and makes recommendations for a renewed program. There is ample evidence that typical drivers can reduce fuel consumption by at least 10% by the way they maintain and operate their vehicles. The original DOE program was reasonably successful in reaching motor vehicle fleets, especially in government. Challenges for a new DECAT program include increasing its outreach to the general motoring public, fostering research and transfer to the marketplace of effective driver feedback devices, and incorporating DECAT training into the driver education and licensing process, nationwide. Depending on the effectiveness of DECAT, motor fuel savings could range up to 10 billion gallons annual.

DRIVER ENERGY CONSERVATION AWARENESS TRAINING: REVIEW AND RECOMMENDATIONS FOR A NATIONAL PROGRAM

David L. Greene

1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The idea that a formal curriculum could be developed to train motor vehicle operators to save fuel was seized upon by the U.S. Department of Energy in the late 1970's and realized as the Driver Energy Conservation Awareness Training (DECAT) Program. A pioneering program was established in Mercury, Nevada which began training instructors and operators of government fleets in 1979. Since then, DECAT's influence has spread beyond the federal government to states, and to a lesser and largely unknown degree, to private fleets and the motoring public. The purpose of this report is to review that effort and to make recommendations about how to achieve the full potential of driver training for fuel efficiency. The report is not intended to be an evaluation of the DOE DECAT program, nor a detailed program plan. It is intended as a master plan which: (i) reviews the content of DECAT, (ii) estimates its potential based on engineering evidence and limited experience, and (iii) describes the elements of a possible new program to realize DECAT's full potential.

Everything a driver does affects fuel economy. Whether he speeds or observes posted limits, changes speeds abruptly or smoothly, anticipates traffic situations or doesn't, keeps his tires properly inflated,

even how the driver plans his travel can have a profound influence on miles per gallon. Unfortunately, the connections between his actions and their effect on energy efficiency are invisible to the driver. As a result, fuel efficient driving techniques are generally not well understood and, being out of sight, they are usually out of mind.

In fact, most actions, taken individually, have very small effects (one half to ten percent) so that an individual would have a difficult time measuring their impact, even if he tried. Yet there is overwhelming evidence from tests conducted by the government, automobile manufacturers, the transportation industry, and consumer groups that the vehicle operator can and does have a profound influence on MPG through his driving behavior, vehicle maintenance, patterns of vehicle use, and choice of vehicle. While the degree of improvement possible is a function of current practice, fuel savings in excess of 10 percent are readily achievable by the average motorist.

1.2 DECAT PROGRAM OBJECTIVES

The objectives of Driver Energy Conservation Awareness Training (DECAT) are:

1. **CONSERVE ENERGY RESOURCES**, by making known to the motoring public driving techniques and information on vehicle ownership and use which can save the average driver at least 10% in normal driving, will enhance highway safety, and will increase the public's preparedness for possible energy emergencies.

2. **INCREASE KNOWLEDGE OF ENERGY EFFICIENT DRIVING TECHNIQUES**, through research.

3. **INSURE DEVELOPMENT OF APPROPRIATE DRIVER FEEDBACK DEVICES,** through research, and promote the transfer of this technology to the marketplace.

DECAT's objective is to educate motor vehicle operators in techniques which can save the average driver at least 10% in normal driving. DECAT's targets are professional vehicle operators, fleet owners and managers, government as well as private fleets, and the over 150 million private individuals licensed to operate vehicles in the United States. In the past, DECAT has focused its training on fleets, both governmental and private. Training a few key individuals in a fleet as trainers themselves has proven to be a very efficient way to reach a great many drivers within the restrictions of a small budget. Attempts were also made to reach the general public through an award-winning film "Running on Empty" and through other public information materials.

An expanded effort would be necessary, however, to reach all 150 million drivers in the U.S. It is feasible to educate the majority of existing drivers, and nearly all new drivers who take formal driver training, in efficient vehicle use and ownership techniques. Chapter 4 presents the key elements of such a plan, including collaboration with the driver training community, development of a formal curriculum and teaching materials, updating the training film and other public information materials, and exploring new low-cost methods of getting DECAT information and training to the public.

DECAT is a technology education program. Its purpose is to educate and train the public in the efficient and safe operation of complex technology: motor vehicles. As such, it is of utmost importance that

DECAT information be accurate and up-to-date. While the basic principles of efficient driving and maintenance are known, there are some issues which remain uncertain. How best to accelerate and to climb hills are two fundamental questions to which we have only vague answers at this point. Enough is known to indicate that the answer depends on vehicle design. Recent dramatic improvements in vehicle fuel economy, achieved by engineering and design changes, raise the possibility that information even 5-10 years old may now be outdated. One possible example is the relationship between speed and MPG. In these and many other areas it is necessary that DECAT have the ability to analyze and evaluate the technical literature and, where necessary, conduct some original research to resolve uncertainties. Thus, an important program objective will be to insure that DECAT provides information and training that is both up-to-date and accurate.

The most important area for further research and development is appropriate driver feedback devices. A central problem for DECAT is the ability and willingness of drivers to maintain efficient driving practices. The chief difficulty is that energy use remains invisible to the driver, who does not see how each action affects MPG. He cannot know whether he has just made an efficient trip to work or a wasteful one. It is very difficult for him to tell when his car may need maintenance to maximize fuel economy. What is required is a device that gives the driver immediate and accurate fuel consumption information, yet is not a distraction from safe driving. The device must provide both instantaneous and cumulative measurements, must be simple to use (preferably fun

to use), and must be cheap. With the arrival of low-cost microprocessors, devices approaching these requirements have been developed. A major objective of the DECAT program should be to work with vehicle and component manufacturers to conduct research leading to the development of appropriate fuel economy feedback devices, and to encourage the transfer of this technology to the marketplace.

1.3 DECAT PROGRAM ELEMENTS

A complete DECAT program would include five major elements:

1. Instructor Training Program
2. Public Information Program
3. Driver Feedback Device Research Program
4. Energy Efficient Vehicle Operation Research Program
5. Driver Education and Licensing Program

1.3.1 Train DECAT Instructors

First and most important is to continue and expand the existing national DECAT training center. Over the past 7 years, the Department of Energy DECAT Center operated by the Reynolds Electrical and Engineering Co. (REECO), Inc. for the DOE Nevada Operations Office has trained over 8,000 drivers and driver instructors in fuel efficient driving techniques. Since 1980, activities have been greatly reduced because of major reductions in financial support. Continuation and expansion of this activity should be the cornerstone of a revitalized DECAT program. The Nevada DECAT Center can serve as the primary center for carrying out training of instructors, and for coordinating information dissemination efforts, as well as research on driving techniques and feedback devices. In the future, funds permitting, the establish-

ment of one new regional DECAT center, strategically located in another part of the U.S., should be evaluated. The Nevada center could concentrate on reaching auto and truck fleets, both public and private, while the second center focuses on developing a curriculum for driver education for licensing, in a way which establishes the connection between DECAT and safe driving techniques. It is essential to have an active center of expertise where instructors can be trained, new teaching methods and new devices tried, and supporting research coordinated with the teaching and information transfer activities.

1.3.2 Get DECAT Information to Motorists

The second critical program effort is to make fuel efficient driver behavior common knowledge in the U.S. The principles of fuel efficient behavior developed and taught at the National DECAT Center need to be communicated to the over 150 million licensed drivers in the U.S. This must be done in a cost-effective manner, probably without expensive advertising. Existing DOE or other government publications with wide circulation, (e.g., state driver manuals) can be encouraged to include the principles of fuel efficient vehicle operation and ownership. Likewise, organizations and publications concerned with other aspects of driver behavior and vehicles could be encouraged to disseminate DECAT information as a benefit to their constituencies.

The DOE Gas Mileage Guide offers an excellent opportunity to provide DECAT information to hundreds of thousands of new car buyers at next to no cost. In fact, most countries which provide new car fuel economy information to the public also include fuel-efficient driving

tips, according to a recent study by the International Energy Agency (OECD/IEA, 1984).

Another element of this effort which can be accomplished almost immediately at very low cost is the production of an updated DECAT film. The existing DECAT film "Running On Empty" was a tremendous success, having been seen by perhaps 3-5 million individuals. This film needs to be brought up to date as soon as possible. DECAT films should serve not only as a means to disseminate DECAT information to the general public, but also as a teaching aid for driver education courses. For this reason it would be desirable to involve the driver education community in the production of a film specifically designed in cooperation with them and bearing their stamp of approval.

1.3.3 Develop Feedback Devices

The third key program element is research and development of devices to provide fuel efficiency feedback to the motorist. Numerous studies have shown that feedback leads to improved conservation behavior only when it is provided simultaneously with performance. Providing appropriate feedback to drivers is difficult since it must be done in a way that is both effective and safe.

A low-cost step which can be taken immediately, is to establish an industry-government advisory committee to identify the key research areas and establish a research agenda. One of the first actions of this committee would be to organize a special conference on devices to aid fuel-efficient vehicle operation, focussing primarily on light duty vehicles. The proceedings of this conference could serve as a summary of the state-of-the-art and indicate the critical areas for research and development.

1.3.4 Conduct Efficient Driving Research

The fourth element is a research effort to support the driver training and education programs. Research will be directed at the verification of any aspects of the present curriculum about which there is some question or need for quantification, and the development of new information about optimal driving strategies. This component of the program is important to maintaining the credibility of the program by insuring the accuracy of DECAT information and keeping up with advances in automotive engineering.

As part of previous DOE DECAT research, Oak Ridge National Laboratory developed computer programs for analyzing optimally fuel efficient driving strategies using computerized simulators of specific automobiles' fuel consumption. These techniques were applied to a simulator developed for a single vehicle. This software can now be used very cost-effectively to analyze optimal driving strategies using up to 15 vehicle simulators developed by ORNL for the Department of Transportation. Such research could contribute greatly to resolving questions which now exist about optimal acceleration and hill climbing.

1.3.5 Promote DECAT for Driver Education

The fifth program element would be a continuing effort to insure that drivers taking formal driver training receive behind-the-wheel training in DECAT techniques. The majority of new drivers, approximately 3 million each year, receive formal driver training. Getting DECAT into the driver instruction curriculum could be the most effective way to reach drivers at a time when they are forming their driving habits. Accomplishing this will require formal coordination with those

organizations representing and serving the driver education community to develop a consensus on a formal curriculum. It will probably also require some research on how to teach DECAT to novice drivers, since questions about the ability of novice drivers to learn DECAT skills effectively have been raised in the past (McKnight et al., 1981). The long-run value of including fuel-efficient driving in the driver instruction and licensing process is tremendous.

1.4 DECAT PROGRAM BENEFITS

1.4.1 Potential Petroleum Savings

The total petroleum consumption to which Driver Energy Conservation Awareness Training (DECAT) techniques can be applied is so enormous that even if only one one-hundredth of the 10% MPG improvement potential could be achieved, a modest $1 million per year program would pay for itself every three days, at today's (1985) fuel prices. Highway vehicles consumed 14.5 quads of petroleum in 1981, 45% of total domestic consumption of petroleum products (Holcomb and Koshy, 1984). That share has increased in recent years. In 1984, gasoline alone accounted for 43% of consumption of petroleum products, 6.7 out of 15.7 million barrels per day (DOE/EIA PSM, 12/84).

The Federal Highway Administration reported 100 billion gallons of gasoline and 16 billion gallons of diesel fuel were consumed by highway vehicles in 1983, and total 1984 motor fuel consumption will be 119 billion. If the full 10% fuel savings potential of DECAT could be achieved, it would be worth $13.9 billion annually, at $1.20 per gallon. Even if only 1% of the DECAT potential could be realized, the savings to consumers would amount to $380,000 per day. In achieving this conser-

vation of national resources and reduction in oil imports, DECAT does not restrict drivers' freedom, or ask them to make sacrifices. Instead, it offers drivers the know-how to control their vehicles and save themselves money. Even if motorists do not fully utilize DECAT techniques in their daily driving, the knowledge of how to maximize efficiency will make them better able to cope with possible future energy emergencies.

1.4.2 Safety

Possibly even more important than energy efficiency and conservation of resources are the indirect safety benefits of following DECAT driving principles. Many of the principles of fuel efficient driving are also key principles of safe driving: 1) awareness, 2) anticipation, 3) observing speed limits, and 4) proper vehicle maintenance. Rather than asking motorists to sacrifice safety for efficiency, DECAT shows them how to enhance both. Indeed, the entire thrust of DECAT training is to increase the driver's control over his vehicle through knowledge (gained by demonstration) of how his actions determine its energy use, and through training in how to exercise control.

2. DECAT: PRESENT STATUS AND PAST ACCOMPLISHMENTS

2.1 THE DECAT PROGRAM

DECAT uses information and training to show individual operators and managers of large fleets what they can do to save money by conserving fuel. Through a variety of means, including intensive instructor training courses, published information, existing educational delivery systems, regional seminars, workshops, and other cost-effective media, the DECAT program's goal is to make the driving population more aware of how they themselves can improve transportation efficiency, conserve petroleum, and save money. The program emphasizes four principal routes to improved fuel economy:

1. Behind-the-wheel techniques - how to drive safely and save gas,
2. Car care and maintenance - how the consumer can protect his investment in an automobile by maximizing MPG,
3. Trip planning and alternatives - how to travel efficiently by planning trips,
4. The purchase decision - how to use available efficiency information in choosing the best vehicle for you.

The average driver is usually surprised to find that he can improve his MPG by over 10% using fuel efficient driving techniques. DECAT training proves these savings to drivers in instrumented vehicles they drive themselves. Via in-car instruction, trainees are able to see the gasoline saved by techniques such as:

- conserving momentum by anticipating manoevres and traffic situations. Avoiding unnecessary braking and acceleration is particularly effective in urban traffic.

- accelerating briskly and steadily. Too rapid or too slow a rate wastes gas.
- avoiding unnecessary idling. Restarting a warmed-up engine costs very little fuel. If you have to think about it, shut it off.
- observing speed limits. Keeping within legal limits is not only safer, it saves money too.

By learning to drive intelligently, but not being afraid to accelerate and go the legal speed limit, drivers can learn to save fuel without wasting time.

Proper car care and maintenance not only contribute to efficiency, but may lead to a longer life for both car and driver. Most actions which help efficiency cost little or nothing. For example,

- maintain maximum rated tire pressure. Soft tires can reduce MPG by 5%.
- use fuel saver grade lubricating oil. Improvements of 2-6% over standard grades are likely.
- use radial, not bias ply tires. Radials give 3-5% better gas mileage, and their longer life more than offsets the higher sales price.
- maintain proper wheel alignment and brake adjustment. Both reduce rolling resistance and make equipment last longer.
- tune-ups, when needed, can also save gas.
- use gasoline with the octane rating recommended by the manufacturer; too little can damage the engine, too much is a pure waste of money.

Any individual car care action, by itself, makes a small contribution to MPG. A program of proper maintenance can have a substantial impact on fuel economy and makes for a safer, longer-lasting vehicle, as well.

Several short trips use more fuel than one long trip covering the same distance. Combining trips, or trip chaining, can accomplish the same result with less traveling and in less time. These are the two fundamental principles of trip planning to save fuel. Since vehicle energy use is invisible to the driver, most people don't realize that short trips taken from a cold start can use twice as much fuel as the same trip taken when the engine is warm. Planning trips so that many errands can be accomplished at once not only saves time and travel, but insures that most of the distance is covered while the engine is in fully warmed-up, efficient operating condition. Research on travel behavior has shown that typically about 60% of nonwork trips are single-destination round trips (Southworth, 1985). By combining some of these trips distance traveled could be reduced and efficiency increased. Furthermore, roughly half of all multidestination trips are not traveled by the most efficient route (O'Kelly and Miller, 1984). There is clearly substantial scope for saving fuel by trip planning.

Choosing which vehicle to buy can be the most important fuel economy decision. Buying a smaller car is not necessarily the best way to improve fuel efficiency. Making the best use of available fuel economy information, such as published in DOE's Gas Mileage Guide, can save more fuel without sacrificing size. Even within vehicle size classes there is a tremendous range of MPG's to choose from. According to the 1985 Gas Mileage Guide, the least efficient subcompacts get 16

MPG and lower on the city test, and 24 and lower on the highway cycle (discounted to reflect actual driving conditions). The most efficient large cars (American made) achieve 20 MPG or better city, and 30 MPG, or higher, on the highway. Popular models of compact cars range from 18 or less in the city, and 23 or less on the highway, to twice that efficiency. With such a range among cars of the same class, there is probably no reason for the consumer to feel he must trade-off size for fuel economy, if only he makes use of available information.

A fuel savings of 10% is possible by following DECAT suggestions in any one of these four areas, as evidence presented in the appendix shows. How much savings can be realized depends on what a vehicle operator is doing now and how assiduously he employs his DECAT program know-how. The primary purpose of the proposed DECAT program is to educate as many operators as possible, as effectively as possible. It is also important that the program conduct enough research to insure that the information it provides is up-to-date and accurate, and try to identify or discover better methods of providing fuel economy feedback to the driver. The latter is key to maintaining fuel efficient driving behavior.

2.2 DECAT INSTRUCTOR TRAINING

The DECAT Instructor Training Program was established in May 1979 by the then Office of Transportation Programs, Office of Conservation and Renewable Energy, U.S. Department of Energy. The program was specifically targeted at fleets and motor pools, within both the government and business sectors. However, materials were also developed and distributed to reach the general driving public. The program's objec-

tive was to provide these organizations with the information they needed to improve their fuel economy by at least 10%.

The DECAT instructor training courses, DECAT for automobiles and DECAT-T for trucks, consist of two-and-a-half day training sessions which are offered twice monthly at DOE's Nevada Test Site near Las Vegas. The courses' curricula include classroom training sessions and, most importantly, behind-the-wheel training in instrumented vehicles. Classroom training includes lectures, a 35mm slide show (graduates are given copies of the slides to use in their own courses), a showing of the film "Running on Empty", and structured discussions. Student instructors are taught procedures for establishing, administering, and teaching a 3-4 hour training course, adapted to the special needs of their organization.

Through a combination of classroom exercises and field experience they learn how to set up a driving course, to take students through that course, and to record and evaluate their performance. One section of the course is devoted to vehicle instrumentation. Various types of instruments are explained, their pros and cons discussed, and trainees are provided all the information needed to order the equipment they will need from manufacturers.

In-car experience is emphasized. Trainees are given the opportunity to prove (or disprove) to themselves, without supervision, that DECAT techniques really work. The final achievement of each trainee is to lay out his own road course at the test site, and show others how they can save fuel by using DECAT techniques on his course.

The instructor training course proved to be remarkably effective. 734 automobile and 121 heavy truck instructors have been trained at the Nevada Test Site DECAT facility since May 1979. These instructors have trained an unknown amount of instructors and students. A follow-up study on the DECAT program was conducted by Orkand Corp. under contract to the Department of Energy, and published in September 1982. The study surveyed 75 individuals out of a total of 155 graduates who attended the DECAT course during the one-year period, May 1979 to June 1980. The interview questions attempted to determine:

1. the characteristics of individuals taking the course,
2. the effectiveness of the DECAT training,
3. the extent to which trainees trained others, and
4. the cost effectiveness of the DECAT programs established by the trainees in their own organizations.

In brief, the study found that DECAT's strategy of targeting its efforts on fleets and motor pools was effective. Graduates were well impressed by the program. Sixty-nine percent of those surveyed rated the program "highly effective", 25% "moderately effective", and 6% "marginally effective". Ninety-four percent of the graduates surveyed said they used the DECAT training materials they were provided at the Test Site, and 81% had already set up courses in their own organizations or had made plans to do so. At the time of the study, at least 1,161 instructors and 483,670 drivers had been trained by the DECAT graduates, most of these in a few very large fleets. An additional quarter-million drivers were expected to be trained. Surprisingly, 60% of those surveyed were providing training to individuals outside their own organiza-

tion. The importance of these results is that they indicate that even a small, one-center DECAT program can be tremendously effective in reaching motor vehicle operators.

As a rule, the trainees found the DECAT program to be cost-effective in their agencies. The organizations reported achieving average savings of 10.6%. The median cost per driver trained was $50. While only six of the 75 graduates surveyed had sufficient information for a cost-effectiveness analysis, five of these showed DECAT to be cost-effective even though the training programs had only just begun. The average payback period reported was 4.4 months, with a maximum of 8.5 months.

The Orkand study identified a few key barriers which a revitalized DECAT program should address. Thirty-eight percent of the graduates reported problems in establishing their DECAT programs, even during this period of rapidly rising fuel prices. Barriers most frequently cited were lack of management support and funding limitations. Both are indications of a lack of confidence on the part of management that a DECAT program will be an effective investment. The DECAT program can address this through such means as developing "marketing packages" containing case studies and other proof that DECAT is a low-cost, low-risk, short-payback investment with significant indirect benefits such as improved safety.

2.3 STATE AND LOCAL DECAT PROGRAMS

DOE's DECAT program has served as a model for states and localities. Instructors trained by DOE's Nevada Center have initiated programs across the country, using pamphlets, slides, movies, and other

aids directly provided by or derived from the DOE program. The national program plays a key role for these state efforts not only as a national resource (providing information, research, and teaching materials) but also in stimulating states, localities, agencies, and private fleets to initiate and continue DECAT programs.

State Energy Offices are not the only agencies interested in driver energy conservation. In many states local governments or private fleets take the lead. SEO's are important to DOE, nonetheless, and since they may be representative of what is going on around the country, we contacted each SEO and inquired about the current status of driver energy conservation programs. Thirteen state energy offices reported having active driver energy conservation programs. Eight others indicated that they had had such programs in the past.

Every state energy office which had or did have a driver energy conservation program stated that their programs had been inspired by DOE's DECAT program (Table 2.1). Most had sent personnel to the Nevada training center for instructor training, others used printed material, or audio-visual materials developed by the DOE DECAT program. Most adapted these materials and the DECAT course to suit their local conditions. Few had estimates of actual energy savings, but those that did were the most enthusiastic about the usefulness of their programs. Mississippi, for example, reported savings averaging 10-15% for DECAT-trained school bus drivers, and is in the process of providing training for all 5000 school bus drivers in the state.

Most state DECAT programs were aimed at a specific group of drivers, usually state or local government employees. Few attempted to reach the

Table 2.1. Status of driver energy conservation activities at STATE ENERGY OFFICES

State	DECAT Program		DOE DECAT Inspired	Energy savings	Comments
	Active	Past			
Alabama	Yes	-	Yes	NA	Modified DECAT adding safety and car care.
Alaska	No	No	-	-	
Arizona	Yes	-	Yes	3–10%	Pima Co. trained 1600 drivers, $600K/yr. savings. Mirana School bus drivers save 10%, $17K/yr.
Arkansas	No	Yes	Yes	NA	Lack of funds. Transfered to Dept. of Educ. for school bus drivers.
California	Yes	Yes	Yes	15%	"GASCAP" program run by DOT/ Caltrans. (Calif. Energy Comm., 1984, p. 21.)
Colorado	No	*	*	NA	
Connecticut	No	Yes	Yes	NA	Trained state vehicle drivers.
Delaware	No	*	*	-	Perhaps in other agencies.
Dist. of Col.	No	*	*	-	
Florida	Yes	-	Yes	NA	Still doing some activities. Some localities, e.g. Tampa, very active.
Georgia	No	No	-	-	Provided some materials to High School driver education programs in past.
Hawaii	Yes	Yes	Yes	NA	Combine with car care clinics. Got state police to add DECAT questions to license test.
Idaho	No	No	-	-	Considering DECAT program.
Illinois	No	Yes	Yes	NA	Chicago Area Transportation Study now doing something in their area.
Indiana	Yes	-	Yes	NA	Just state drivers (have waiting list) considering expansion to private fleets.
Iowa	No	*	*	-	Have an energy efficiency resource guide for driver education courses.
Kansas	No	Yes	Yes	-	Considering starting a DECAT program.
Kentucky	Yes	-	Yes	NA	Just beginning a renewed program. Combine DECAT and car care clinic.
Louisiana	No	Yes	Yes	NA	Previous program was aimed at High School driver education.
Maine	No	No	-	-	Ridesharing program only.
Maryland	Yes	Yes	Yes	10%	Present program consists of DECAT training for high school driver education students. Have developed curriculum and instructional aids.
Massachusetts	No	*	*	-	
Michigan	Yes	Yes	Yes	NA	Organizing a fleet management program of which DECAT is part.
Minnesota	No	*	*	-	
Mississippi	Yes	*	*	10–15%	Training all 5000 school bus drivers, will expand to all state operators. Consider DECAT very successful.
Missouri	No	*	*	-	
Montana	No	*	*	-	Distribute some pamphlets which are apparently not DECAT material.
Nebraska	No	Yes	*	NA	Past "efficiency van" program very successful.
Nevada	No	Yes	Yes	NA	Trained state employees, school bus drivers.

Table 2.1. (Cont'd)

State	DECAT Program		DOE DECAT Inspired	Energy savings	Comments
	Active	Past			
New Hampshire	No	*	*	-	Considering starting DECAT program. Have had successful car care program.
New Jersey	No	*	*	-	Concentrating on vanpooling and ridesharing.
New Mexico	No	Yes	Yes	0.032×10^{12} BTU 1981–84	Incorporated in defensive driving course for state employees.
New York	Yes	Yes	Yes	NA	Low level of effort now. Modified DECAT to N.Y. purposes.
N. Carolina	No	*	*	NA	Car care and van care clinics.
N. Dakota	No	Yes	Yes	NA	Primary target was state police and DOT.
Ohio	No	No	-	-	Did send person to Nevada DECAT course but never started program.
Oklahoma	No	*	*		Intend to start a program for fleet owners, to include DECAT.
Oregon	No	No	-	-	
Pennsylvania	No	No	-	-	
Rhode Island	No	No	-	-	Interested in DECAT training.
S. Carolina	No	No	-	-	
S. Dakota	No	No	-	-	
Tennessee	No	Yes	Yes	1979–81 1.15 TBTU	Planning a DECAT-type course for vanpool operators using oil overcharge money.
Texas	No	No	-	-	
Utah	Yes	Yes	Yes	1982 0.4 TBTU 1983 0.7 TBTU 1984 1.4 TBTU	Energy savings calculated by assumption. Have had trouble getting DECAT into safe driving courses.
Vermont	No	*	*	-	State police had program some years ago.
Virginia	Yes	Yes	Yes	6.7–8.7%	Just completing last group, will terminate. Only 200 local gov't, and school board personnel trained. Less than 10% able to start own program.
Washington	No	*	*	-	
W. Virginia	No	*	Yes	-	Only have film and printed material.
Wisconsin	No	No	-	-	
Wyoming	No	*	Yes	NA	Only includes film and printed material. No training.

*Person now in charge of transportation energy conservation programs did not know whether there had been a previous DECAT program or whether the DECAT program had been inspired by DOE's DECAT program.

- Not available.

NA — Energy savings estimates were not available.

general motoring public and those that did, did not attempt to train drivers but only to get information to them. Hawaii and Georgia reported some success in getting DECAT materials into driver education and licensing programs. New Mexico incorporated DECAT into the defensive driving curriculum for state employees. In brief, there are about as many variations of DECAT as there are agencies which implemented DECAT programs.

States which discontinued DECAT programs most often cited as reasons lack of funds and waning interest due to reduced fuel prices and plentiful supply. Several states, however, are considering restarting DECAT programs using oil overcharge payments. These settlements for oil company overcharges during periods when oil price controls were in effect are returning tens of thousands of dollars to state energy offices, earmarked for transportation. Based on our conversations with them, it is clear that the states will once again turn to DOE for training of personnel and information on DECAT. This renewed interest will provide both an opportunity and a challenge to the DOE DECAT program.

3. DECAT'S ENERGY SAVING POETENTIAL

The scientific evidence presented in the appendix, and the actual achievements of DECAT graduates show that DECAT techniques can indeed improve the average driver's fuel economy by at least 10% in normal driving. Because DECAT know-how applies to every aspect of highway transportation, the total energy demand to which these savings can be applied is reasonably well known. There is great uncertainty, however, about the current prevalence of efficient driving techniques, the extent to which DECAT driving will be adopted, and the ability and willingness of drivers to continue driving efficiently. Nonetheless, one thing is certain: the energy and petroleum saving potential is enormous.

The highway transportation sector consumed 119 billion gallons of gasoline and diesel fuel in 1984 according to the Federal Highway Administration (FHWA). Thus, despite dramatic increases in the technical efficiencies of cars and trucks sold, energy use in highway transportation continues to increase.

Ten percent of highway energy use would be more than 11.9 billion gallons per year. The enormity of this potential can be appreciated by comparing it to the total petroleum use of other sectors. Ten percent of highway petroleum use is more than the total petroleum consumption of the electric utilities and nearly as much as the residential and commercial sectors combined (Figure 3.1).

At March 1985 prices (114.5 cents/gal. for gasoline and 129.1 for diesel), the value to consumers of a ten percent saving in all highway petroleum use would be approximately $13.8 billion annually. Only one percent of $13.9 billion would pay for a $1 million-per-year program in

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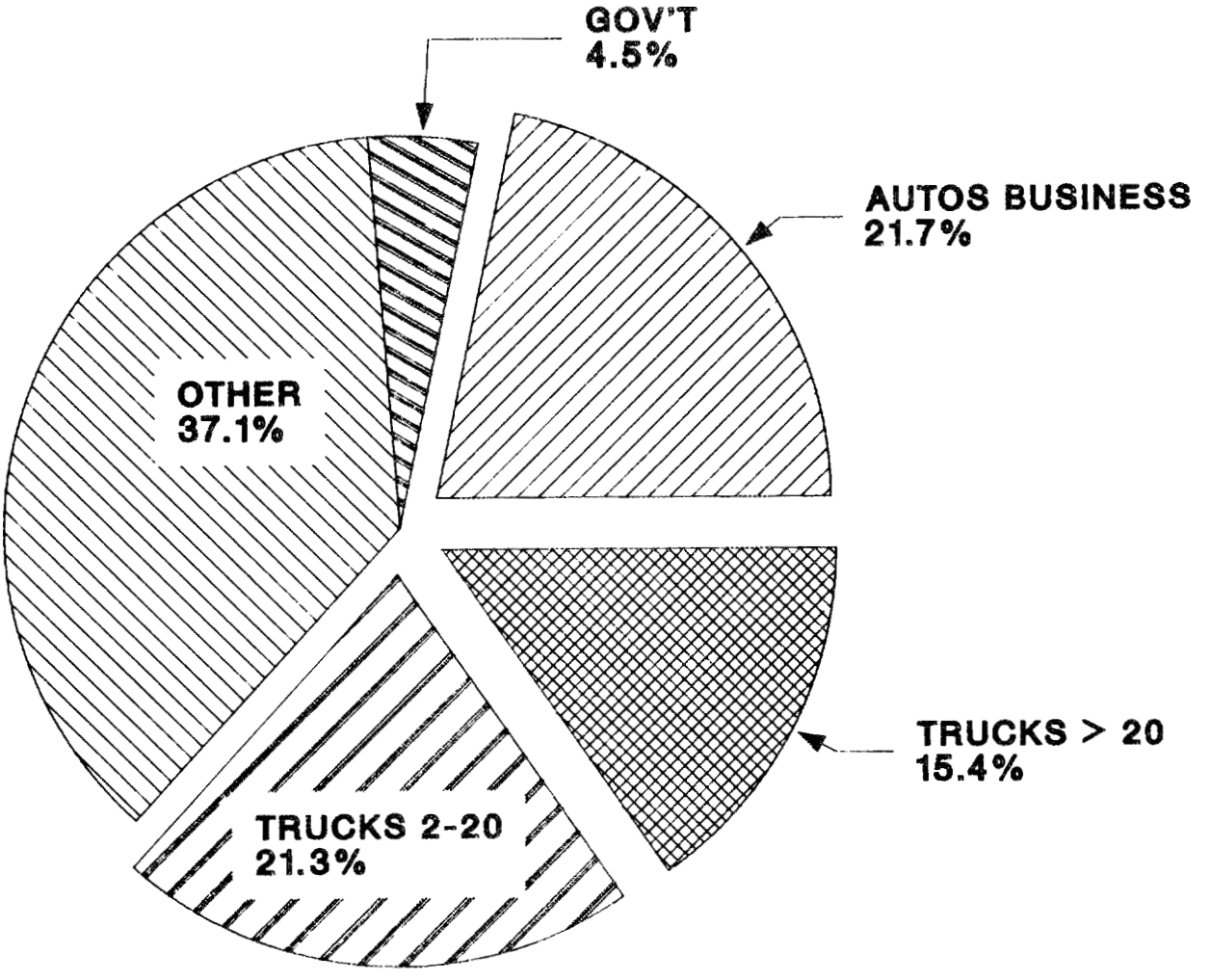

Fig. 3.1. Automobile and truck fleets consume more than 27 billion gallons annually.

three days. The question is how much of this enormous potential saving DECAT could actually stimulate. There is no way to accurately estimate this number since it depends entirely on how successfully the program is carried out, and on the success of research on driver feedback devices, improved training techniques, and better information about fuel efficient driving strategies.

3.1 ENERGY USE BY VEHICLE FLEETS

It is useful to break down the total target energy use by vehicle type, and by fleet versus household use (Figure 3.2), to help in deciding what DECAT priorities should be and what might be achieved by various strategies (e.g., focussing on fleets to maximize impact of instructor training versus focussing on households to attack the area of largest potential). Fleet vehicles consume on the order of 27 billion gallons of fuel annually. Automobiles in fleets of ten or more used an estimated 11.1 billion gallons of motor fuel in 1982.

There were an estimated 6.9 million automobiles in the United States in fleets of 10 or more vehicles in 1982. These vehicles probably accounted for almost 1.4 quads of energy use (Table 3.1). Including police vehicles, civilian government vehicles accounted for about 0.15 quads of energy in 1982, or just over 1 billion gallons of fuel. A DECAT program which successfully reached only 10% of these vehicles could save about $12 million annually.

Trucks in fleets accounted for 15.6 billion gallons of fuel use in 1977 (Table 3.2). Consumption was roughly equally divided between fleets of 2 to 5, 6 to 19, and 20 or more vehicles in size. Judging from published articles and papers, and on participation in the Joint

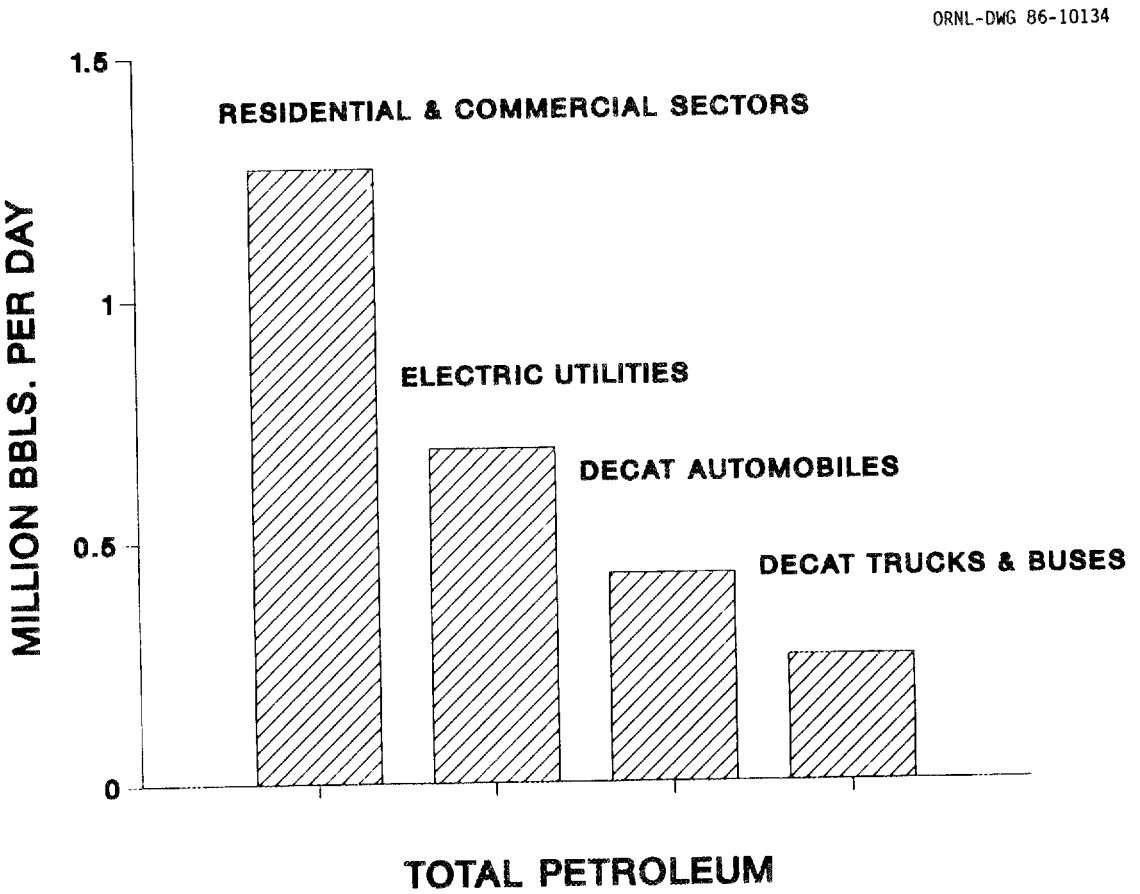

Fig. 3.2. DECAT's total energy saving potential compares to total petroleum use in other sectors.

Table 3.1. Fleet automobile stocks and usage patterns by sector (fleets of 10 or more)

Sector	Average annual travel per vehicle, 1977	Number of vehicles, 1982 (thousands)	Average size of fleet 1977	Energy use, 1982
	Miles			Trillion Btu
Police	33,000	223	506	60.5
Government	17,000[a]	603[b]	1,428[a]	84.3[b]
Utilities	12,000	530	137	52.3
Taxi	43,460	141	31	66.6
Auto rental	18,000	457	1,040	67.6
Business (25+)[c]	27,000	2,548	205	565.8
Business (10-24)[d]	26,000	738	e	157.8
Other sectors	24,000	1,663	e	328.2
All sectors	e	6,903	230	1,383.1

[a]State and local nonpolice.

[b]Includes federal government vehicles.

[c]Fleets consisting of 25 or more automobiles.

[d]Fleets consisting of 10 to 24 automobiles.

[e]Not available.

Source: Holcomb and Koshy, 1984, Transportation Energy Data Book, Edition 7, p. 2-38.

Table 3.2. Truck fleets and energy use, 1977

Fleet size	Number of trucks (10^6)	Total annual miles (10^9)	Average mpg	Fuel use (10^9 gal.)
2 to 5	4.27	51.70	9.3	5.6
6 to 19	1.74	30.78	7.1	4.3
20 or more	1.44	34.49	6.1	5.7

Source: Calculations based on 1977 Truck Inventory and Use Survey.

Industry-Government Truck and Bus Fuel Economy Program, it appears that a great many of the larger truck fleets have already adopted DECAT techniques. Most success stories in the literature describe fleets of tens, and more frequently hundreds of vehicles. However, even if one targeted only fleets of less than 20 trucks, two-thirds of truck fleet energy use would be addressed. Ten percent of the energy use of these trucks is approximately one billion gallons per year, worth over a billion dollars a year.

Trucks in smaller fleets tend to be smaller and lighter, as Table 3.3 shows. Gasoline engines are more prevalent, and fuel efficiency equipment is less common. As Table 3.4 illustrates, there is a consistent tendency for the adoption of fuel economy options to decrease with decreasing truck GVW. While 81.7% of new trucks over 33,000 lbs. GVW are ordered with radial tires, only 14.9% of trucks between 10,001-26,000 lbs. GVW are so equipped. The smaller trucks tend to be driven fewer miles per year, and have higher MPG, thus increasing the payback period for fuel economy options. In most cases, however, these options are still highly cost-effective. Information and training could speed their adoption on smaller trucks as it did on larger trucks.

Because fleet size is smaller, these trucks will be more difficult to reach via employer-based marketing and instructor training. At the same time the potential returns to a DECAT program are larger, both because of the greater number of trucks and the greater potential to introduce fuel saving equipment.

Other vehicle fleets (e.g., taxis, school buses, utilities, etc., see Table 3.1, above) also consume significant amounts of fuel. It is

Table 3.3. Trucks (thousands) by fleet size, 1977

Fleet size	Light (<10,000)	Medium (10,000-26,000)	Light-heavy (26,000-33,000)	Heavy (>33,000)
2 to 5	3,068	520	323	356
6 to 19	931	240	173	397
20 or more	676	197	126	446

Source: 1977 Truck Inventory and Use Survey.

Table 3.4. Use of fuel economy options by larger trucks

Option	10,001-26,000 lbs. GVW	26,001-33,000 lbs. GVW	Over 33,000 lbs. GVW
Diesel engine	38.1%	61.7%	99.3%
Radial tires	14.9%	19.5%	81.7%
Variable fan	67.9%	71.4%	96.0%
Speed governor	4.0%	-	3.5%
Aerodynamic dev.	-	-	33.4%
Fuel econ. diesel	-	-	68.7%

estimated that all automobile fleets of 10 or more vehicles consumed 11.1 billion gallons of gasoline in 1982 (Holcomb and Koshy, 1984). If we add to this the 9.9 billion gallons consumed by truck fleets of less than 20 vehicles, the total target amounts to 21 billion gallons, about 18% of total highway energy use. Clearly, fleets are an important target for DECAT, and one which the program has considerable experience addressing. To realize its full potential, however, the DECAT program must broaden its scope and attempt to reach the general driving public, and independent truckers.

3.2 HOUSEHOLD VEHICLES AND INDEPENDENT TRUCKS

Individual households consume most highway motor fuel. The Energy Information Administration (1985) estimates that in 1983 households consumed 78.4 billion gallons of gasoline, 1.1 billion gallons of diesel fuel, and 0.7 billion gallons of gasohol. Total household motor fuel consumption amounted to 10 quads, more than half of all energy consumed in the entire transportation sector (19 quads), and one third of the nation's total petroleum consumption. Automobiles accounted for 60.5 billion gallons, pick-up trucks for 13.3 billion gallons, and other vehicle types for the remaining 14.6 billion gallons. The sheer size of this energy use demands that DECAT address itself to the household sector.

According to the EIA (1985), the average efficiency of automobiles was 16.0 MPG. Pick-up trucks were even less efficient (13.3 MPG). The fact that light duty vehicles in the U.S. achieve in actual use 10-20% lower fuel economy than they are theoretically capable of achieving, as

indicated by dynamometer tests, is well known and has been extensively studied (e.g., McNutt et al., 1982; Hellman and Murrell, 1982; McKenna and South, 1982; Schneider et al., 1982). The EPA has attributed the shortfall to a variety of factors (EPA, 1980). A large number of these factors have to do with driver behavior, vehicle maintenance (including types of lubricants and tires), and usage patterns (including short trips from a cold start): factors addressed by DECAT and amenable to improvement by following DECAT techniques.

According to the 1977 Truck Inventory and Use Survey, there were nearly a quarter million heavy trucks (over 33,000 lbs. GVW) in use in the U.S. which were not in fleets (operated independently, which is not exactly equivalent to an independent owner-operated heavy truck). These trucks traveled 8.4 billion miles and, assuming an average efficiency of 4.8 MPG (the average for all heavy trucks), consumed approximately 1.7 billion gallons of fuel. Unlike heavy truck fleet operators, there is little evidence that independent operators have successfully implemented DECAT techniques. Because of the significant cost savings which these operators can derive from DECAT methods, they will be a major target of the DECAT program.

3.3 SUMMARY: ENERGY SAVINGS POTENTIAL

The eventual energy savings of the DECAT program will depend on a number of factors:

1. how many of each target group can be reached by the DECAT program,

2. how successful the program is in convincing drivers and operators to adopt DECAT methods,
3. how effectively these methods are implemented by individuals, and
4. how persistently and rigorously the DECAT techniques are used over time.

DECAT is not a magical quick-fix which instantly returns fuel savings which persist forever. Instead it is a collection of techniques which must be learned and applied. Each technique individually returns only a small percentage in savings. Taken together, the savings are substantial. Thus, results depend on the effectiveness of the teaching, and on reinforcement of the learned behavior. The DECAT program plan recognizes that improvements are needed in both of these areas, most especially in the area of driver feedback.

4. OUTLINE OF A COMPLETE DECAT PROGRAM

4.1 PROGRAM SCOPE

A complete DECAT program would consist of five major elements. The first, and most important of these is the expanded DECAT Instructor and Driver training course, already in operation, at DOE's Nevada Test Site. This program, with its long experience in driver energy conservation, is the core of the DECAT effort. It will serve as the center for transferring DECAT techniques to fleets and private individuals, and as a proving ground for new techniques, new feedback devices, and new teaching curricula. It will be the focal point of the DECAT program. Four other program elements would be necessary to address important research problems and effectively reach the maximum number of drivers. The five program elements are:

1. Instructor Training,
2. Public Information,
3. Driver Feedback Device Research,
4. Energy Efficient Vehicle Operation Research,
5. Driver (Safety) Education and Licensing.

The relationship between program elements is depicted in Figure 4.1, which illustrates the central role of the Nevada training center. The three research activities (feedback device, efficient vehicle operation, driver education and safety curriculum development) not only generate new information and techniques for the training center, but receive input and feedback from the training center concerning what is needed and what works in practice. Other elements provide information about safe and fuel efficient vehicle operation which may be valuable to

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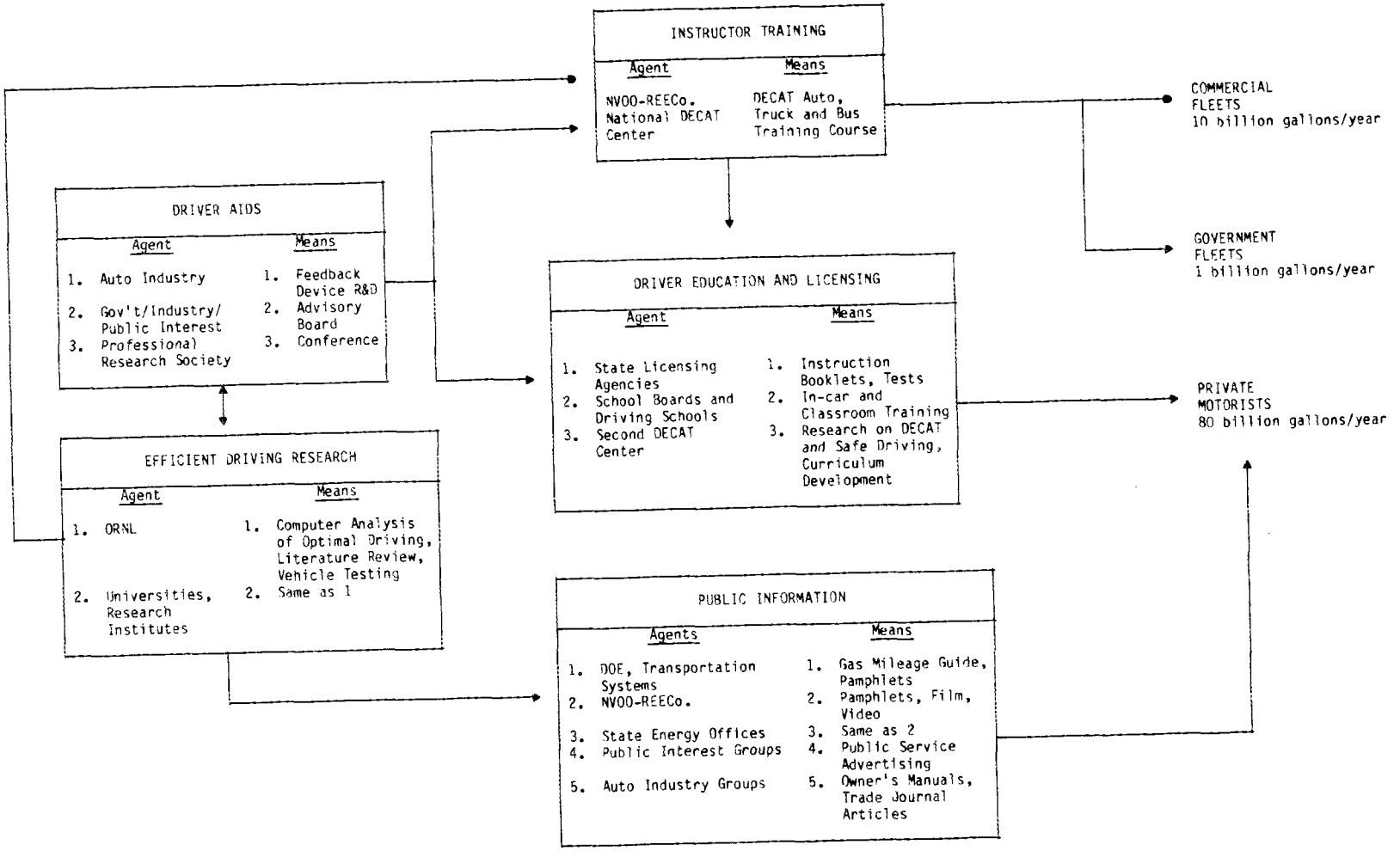

Fig. 4.1. DECAT program elements.

the public information program. The public information program educates the general driving about safe and efficient vehicle operation.

A complete DECAT program should include research efforts in two key areas: 1) verification of aspects of the current curriculum about which there is some question of fact or need for quantification, together with development of new information about optimal vehicle operating strategies, 2) research dealing with the selection or design of appropriate driver feedback devices. Both of these areas are important to maintaining the credibility of the DECAT program, keeping up with advances in automotive engineering, and solving a key problem: how to increase the likelihood that drivers will continue to drive efficiently as time goes on.

The DECAT program also includes two elements whose purpose is to make fuel efficient driver behavior common knowledge in the United States. The principles of fuel efficient driving need to be communicated to the over 150 million licensed drivers in the U.S. This will have to be done in a cost-effective manner, probably without the benefit of expensive advertising. A two-pronged attack is proposed. The first part is a public information effort, making the greatest possible use of essentially free publicity. Existing DOE or other government publications with wide circulation (e.g., the annual Gas Mileage Guide, state driver manuals, etc.) would be encouraged to include the principles of efficient driving. Press releases could be used, where appropriate, and events dramatizing the energy and cost savings carried out to attract the attention of the news media. Organizations and publications concerned with other facets of driver behavior (e.g., safety, environmental

quality, etc.) would be encouraged to disseminate DECAT information as a benefit to their constituencies. DECAT training staff will conduct seminars and workshops at appropriate forums around the country to publicize DECAT and the Nevada-based training program. Finally, an updated DECAT film, similar to or derived from the successful previous DECAT film "Running on Empty" will be produced and made available to interested groups.

The second, and in the long run perhaps the most important part of an information campaign, would be a continuing effort to insure that new drivers receiving formal training are given behind-the-wheel instruction in fuel efficient driving. This will require working cooperatively with the appropriate professional driver training organizations to incorporate DECAT into the standard curriculum.

4.2 PROGRAM ELEMENT DESCRIPTIONS

The heart of an energy efficient driver program is the combination of facts to be taught, methods for teaching them, and means for insuring retention of learning. It is absolutely crucial, therefore, to have an operating training center where individuals can be trained, curriculum can be developed and tested, and new methods, techniques and devices can be proven. To establish this foundation, a revitalized DECAT program should be built upon the already existing program at the Nevada Test Site. In order to meet program objectives, the Nevada center will need to expand its activities in certain areas and have access to research support in others. The current effort at Nevada is aimed primarily at training instructors from commercial or governmental vehicle fleets. While this is a large and important pool of drivers, the vast majority

of energy used in highway transportation is accounted for by households and individual owner-operators. These individuals must be reached. The program elements described below are designed to reach all drivers, to provide accurate and useful information, to insure that DECAT principles will become a basic part of learning to drive, and to make the benefits of efficient driving visible to the driver.

4.2.1 Instructor Training

Instructor training activities should be continued and expanded. Instructor training at DOE's Nevada Test Site has been the most effective means of disseminating fuel efficient driving techniques to date. A large part of the effectiveness of this effort derives from the hands-on, in-vehicle experience which is the central part of the training. Trainees are encouraged to see for themselves how the DECAT techniques can save fuel. Many believe that this is the only way to convert skeptics to believers.

Training representatives from commercial and governmental vehicle fleets has proven to be a very effective method of multiplying the efforts of DECAT instructors. The DECAT program should expand its efforts to reach vehicle fleets through seminars and workshops at trade shows and conventions, articles in trade magazines, direct mailing, and through a DECAT newsletter. A ten-minute videotape containing the DECAT message has already been produced to be sent to fleets requesting more information about the program, so far with good results. The DECAT newsletter provides a forum for DECAT graduates to communicate their experiences and for disseminating new information.

A key element in the campaign to reach commercial fleets should be the development of a marketing package containing case-study examples of successful commercial DECAT programs. Many such cases reportedly exist but the documentation is lacking. The Nevada Center should attempt to secure the cooperation of a few fleets as soon as possible, to obtain documented success stories. Documentation of new success stories should be a continuing effort of the instructor training program.

The training program should also address state and local government fleets, an area in which DECAT has had past successes. Once again, these successes should be documented on a continuing basis. In this effort, DECAT should coordinate with DOE's State and Local Assistance Program (SLAP). It is crucial to work in cooperation with SLAP in order to magnify the impact of the DECAT program. At present, we have determined that thirteen states include DECAT as a line item in their state energy conservation plans. No doubt, these programs could be assisted by the Instructor Training program in Nevada, and other states could be encouraged to carry out DECAT programs. Many other states have begun or plan to begin DECAT programs using oil overcharge payments. These states can benefit greatly from the Nevada Instructor training course, and many are considering taking it. The Nevada Center should directly contact the State Energy Offices to insure that all states are aware of their resources.

The Nevada Test Site DECAT program is capable of training a maximum of 3,000 instructors per year. There are approximately 30,000 fleets in the U.S. with more than 10 vehicles (Holcomb and Koshy, 1984). Since not all fleets will want training in a given year, and since there will

be some turnover of fleets and need for retraining, the NTS center is probably large enough to handle most, if not all, instructor training for fleets in the U.S.

4.2.2 Public Information

The purpose of this element is to inform as many of the 150 million drivers as possible about the principles of energy efficient vehicle operation. It would draw on existing DECAT publications and new information developed by the other program elements. It has two major parts: 1) continuation and expansion of the Nevada Test Site DECAT program and the future addition of one more regional center, and 2) the development of a low-cost public information program.

The NTS instructor training program would not be able to reach all 150 million licensed drivers in the U.S. It is certain that a substantial amount of DECAT information would be transferred to the public by fleet drivers by word of mouth. However, a more direct approach is needed. It would be useful to establish one additional regional center which would concentrate primarily on reaching the general public, in the same way that the Nevada center has concentrated on reaching fleets. Areas in which this second center, if established, would have a primary interest, are establishing DECAT as a part of the driver education curriculum in the U.S., the relationships between DECAT and safe driving, and the evaluation of driver feedback devices.

The Nevada Center should share responsibility with DOE for implementing a low-cost public information program. This would involve printed matter, films, and innovative use of existing government publications (such as the DOE Gas Mileage Guide, and state driver instruction

manuals), public service advertising (such as public TV spots), and encouraging articles about DECAT in trade and special interest periodicals.

Including DECAT principles in the DOE Gas Mileage Guide is a step which can be taken immediately at very low cost. A recent study by the International Energy Agency (IEA) showed that all but one member country which published a fuel efficiency guide also included information on fuel efficient driving or factors affecting fuel efficiency (Table 4.1). Such information is valuable not only because it informs consumers about efficient vehicle operation but also because it helps explain why actual mileage may differ from the official estimates. In this way it improves consumer understanding and trust in the official estimates.

Table 4.1. Information presented in 1983 fuel efficiency guides in IEA member countries

Country	Agency responsible for publication	Guidelines for fuel efficient driving or factors affecting fuel efficiency
Australia	Dept. of National Devel. and Energy	Guidelines
Canada	Transport Canada	Factors
Denmark	Ministry of Transportation	Both
Germany	German Automobile Industry	Nothing
Japan	Ministry of Transport	Guidelines
Netherlands	Ministries of Affairs and Transport, and others	Guidelines
New Zealand	Ministry of Energy	Guidelines
Sweden	National Board for Consumer Policies	Both
U.K.	Department of Transport	Guidelines
U.S.	Dept. of Energy and EPA	1985 Nothing, 1983 Guidelines

4.2.3 Driver Feedback Device Research

Just as important as the problem of reaching all 150 million drivers in the U.S., is the problem of insuring that they retain and practice what they have learned. The DOE report "Driver Aid and Education Test Project, Final Report," (DOE/CS-004, July 1978) noted that while the immediate effect of the DECAT training was much greater than originally estimated, the degradation effect over time was also much greater. Perhaps due to loss of learning, perhaps due to loss of enthusiasm, energy savings from DECAT training apparently do decrease over time. Ideally, the money saved by using DECAT techniques would be reinforcement enough. This might be true, were it not for the fact that drivers are not likely to notice, and indeed would have difficulty measuring, the percentage saved on each trip. There is general agreement that an immediate feedback device is needed to provide instantaneous, continuing, positive reinforcement to the DECAT-trained driver. What type of feedback is needed and how it should be provided to the driver are important research questions.

Feedback devices may also be useful to the average driver for training himself in his own vehicle, enabling him to see and believe as well as providing continuing reinforcement for fuel efficient behavior. To date, the most effective device appears to be a simple vacuum gauge. Unlike fuel flow meters which have a damped response which lags actual fuel use by several seconds (smoothing out sudden actions which are often wasteful), a vacuum gauge responds immediately. Yet it has serious drawbacks and could be improved considerably. Although vacuum pressure is nearly perfectly (negatively) correlated with fuel

consumption for a given engine rpm, requiring the average driver to make this calculation in his head may not be reasonable. Indeed, the DOE report cited above concluded that while vacuum gauges were useful as an instructional aid, they did not seem to make a measurable improvement in continued energy savings either by trained or untrained drivers. Some have also raised questions about the safety of dashboard-mounted vacuum gauges. Since DECAT training stresses safe driving principles, it is imperative that the feedback device not impair safe driving in any way.

Vacuum-based devices which directly calculate fuel consumption have already been developed in experimental designs (International Journal of Vehicle Design, 1984). The concepts on which they are based have been proven to accurately reflect on-road fuel consumption (Rose et al., 1982). A computer "map" of fuel consumption versus engine rpm and manifold vacuum is contained in a micro-chip. Rpm and vacuum are measured instantaneously, which permits instantaneous, as well as cumulative, calculations of fuel use to be made and displayed for the driver, using any type of display desired.

Experimentation with instantaneous mpg and fuel flow instrumentation should be carried out at DECAT training centers. The research will focus on how the instruments affect the persistence of DECAT driving techniques over time and how they are perceived by the driver. It is crucial that the automotive industry, as well as those concerned with automotive safety be involved in this research. Bringing the automotive industry in at an early stage is key to insring that successful technologies will actually be adopted by manufacturers. An advisory committee should be established with members from the automotive indus-

try and safety interests. The purpose of this committee would be to guide the research and to speed the transfer of technology developed to the marketplace.

An effective way to begin would be to hold a conference on Driver Aids for Fuel Efficiency. The conference could be sponsored by DOE and organized with the assistance of the advisory committee, perhaps through the auspices of a non-profit scientific or engineering organization such as the Society of Automotive Engineers or the Transportation Research Board. This conference would review the state of the art and generate suggestions for a research agenda.

4.2.4 Driver Education and Licensing

The majority of new drivers, approximatley 3 million each year, receive formal, behind-the-wheel training. Getting DECAT into the driver instruction curriculum could be the most effective way to reach new drivers at the time when they are forming driving habits, and to institutionalize training in efficient driving practices. This can be promoted in two ways. The first is to work with the driver education community to develop a standard, formal, written DECAT curriculum for use in driver education courses. Materials have been developed which can serve as a starting point for this effort ("Driver Efficiency Program Manual," DOE/CS/55957-1, May 1980; "Driver Energy Conservation Awareness Training," D615C mimeo, U.S. DOE, Nevada Operations Office, undated). In addition the program has developed a film, a videotape, slide shows, and other teaching materials. The Maryland Energy Office has already had some success in getting DECAT into high school driver education classrooms. They have developed instructor and student

manuals, slide presentations, and a film (MEETS, 1983). They have obtained commitments from local school boards to include DECAT in their curricula, and have already trained 60 driver education teachers.

Building on these experiences and resources, and drawing upon the practical experience of DECAT instructors, a formal driver training curriculum should be developed, with the active participation of the driver education community. The DECAT program could then work towards the adoption of DECAT techniques in high school, college, and other driver training courses, nationwide.

At the same time, an effort would be made to make DECAT information available where new drivers will see it. The program would encourage state motor vehicle departments, or whichever agency is responsible for licensing drivers, to include DECAT driving tips in their instructional materials for driver certification. Some states (e.g., Hawaii) have already had some success in doing this.

In order for these efforts to be fully successful, the safety benefits of DECAT techniques will have to be clarified and emphasized. One may anticipate some resistance from the driver education and safety communities on the grounds that there is already a great deal to teach new drivers and that safety should be emphasized. Research demonstrating the linkage between efficient driving and safe driving would be very helpful. Two key DECAT principles: 1. awareness of other vehicles and the environment ("perceptual scanning"), and 2. anticipation of traffic conditions ("predicting"), are well recognized, important psychological functions for safe driving (OECD, 1976, pp. 22-23). Scattered evidence that fleets implementing DECAT programs also reduce accident rates also

apparently exists (personal communication, Mr. Boris Hubar, Reynolds Electrical and Engineering Co., Las Vegas, NV). This information should be compiled and the necessary research carried out to demonstrate the link between DECAT and safe driving.

One study (McKnight et al., 1981) questioned whether novice drivers were sufficiently skilled to be able to learn and carry out DECAT techniques. While this study based its findings on tests which did not include the use of driver feedback devices such as used in DECAT training (e.g., vacuum gauges, fuel flow meters) and is thus questionable, the issue of when DECAT techniques can best be learned is appropriate to evaluate before beginning an all-out push for DECAT in driver education.

In summary, some additional research is needed along with curriculum development before DECAT can be successfully incorporated in the driver education and licensing process. Because of the long-run potential of this strategy for reaching nearly all drivers with behind-the-wheel training, however, this remains an important priority for an expanded DECAT effort.

4.2.5 Energy Efficient Vehicle Operation Research

The purpose of this task is to develop and verify information on fuel efficient vehicle operation to support DECAT curriculum and information program elements. Obviously, having accurate and up-to-date information is essential to the program. There is no fixed agenda for such a research effort; it should respond to the needs of the program.

The first step should be a critical review of information in the DECAT curriculum to insure that it is supported by the literature on

vehicle efficiency. Much of that literature has already been reviewed in the process of preparing this plan (appendix).

From time to time it will be necessary to conduct specific engineering tests to answer questions about fuel economy effects of particular actions. In the past, the DECAT program has investigated the effect of running car air conditioners versus opening windows on fuel economy at highway speeds, to resolve conflicting claims (Roberts and Rose, 1982). Other questions such as this can be resolved through engineering analyses and controlled testing. The DECAT program should have the resources to resolve such issues.

The problem of optimal vehicle control for vehicle fuel economy is particularly difficult to solve by experimentation with an instrumented vehicle. Taking repeated measurements is costly and time consuming, and it is difficult, if not impossible, to control for all the factors (e.g., wind, slope, temperature, traffic conditions) which can significantly affect fuel consumption. In the end, the best that can be obtained are results valid for the particular vehicle tested. Yet there are many important questions which remain to be resolved, such as optimal acceleration rates and optimal hill climbing strategies.

An alternative is to use vehicle simulators and to carry out the analysis on a computer. This requires a set of accurate, fast simulators of on-road fuel economy. A set of 15 such simulators, representing a cross section of vehicles now on the road has recently been completed by Oak Ridge National Laboratory for the Department of Transportation. The technique used was developed under the sponsorship of DOE's previous

DECAT program (Rose et al., 1982). These simulators are now available for the analysis of optimal driving strategies.

This approach is now being used to investigate optimal acceleration rates and provide up-to-date information on the effect of highway speed on fuel consumption. Other driving tasks such as hill climbing and stop-and-go driving are also being analyzed for most of the 15 vehicles. The results will provide important, scientifically supported, information on optimal driving which can be used in DECAT training.

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APPENDIX

DRIVER BEHAVIOR, MAINTENANCE AND FUEL ECONOMY

A.1 AUTOMOBILES AND LIGHT TRUCKS: DRIVER BEHAVIOR, MAINTENANCE, AND FUEL ECONOMY

Everything a driver does affects his vehicle's fuel economy. Most of us are not aware of how much we influence MPG because we can't see the energy being consumed. Not knowing what actions to take to save fuel, together with the invisibility of fuel saved or wasted insures that drivers will use more fuel than they really want to. Research on building energy use has shown that making energy use visible by providing direct feedback to consumers can make a difference of 20% or more in total household energy use (Stern, 1984). DECAT is designed to give drivers control over the fuel they consume by educating them about how their actions determine fuel use, and by making fuel use directly and immediately observable. This appendix reviews what is known about: 1) how driver behavior affects fuel consumption, 2) how vehicle maintenance affects fuel consumption, and 3) how successfully various driver feedback devices help drivers conserve fuel. Since 1970, a considerable amount of research has been conducted, especially on topics 1 and 2.

Quantitative measurements of the effects of each on automotive MPG indicates that the program goal of providing information and training which can achieve a 10% efficiency improvement, is conservative.

A.2 THE INFLUENCE OF DRIVER BEHAVIOR ON FUEL ECONOMY

Rigorous studies of the effects of driver behavior on fuel consumption date back to at least the 1950's and 1960's. A 1959 study in

London, England (Roth, 1959) based on repeated measurement of 5 drivers traveling the same urban route at the same average speed in the same vehicle, found variations in fuel economy of 20%. Another British study (Everall, 1968) found a range of variation of +/- 12% for drivers over a varied urban and rural route. A more recent study in Finland (Alppivouri et al., 1979) using a similar approach found a range of variation of +/- 15%. A major study, involving test trials, by the British Transport Road Research Laboratory (TRRL, 1981) looked at specific components of driving cycles. The TRRL study found variations of up to 70% for acceleration strategies, 20% for braking strategies, and 36% for cornering strategies. An empirical test involving 418 drivers tested the ability of drivers to improve fuel economy by changing their driving styles. Drivers instructed to drive efficiently as opposed to their normal style were able to improve their efficiency, on average, by 22%, over an urban, lightly trafficked road network. Average speed, however, fell by 15%. Without reducing speed it was found that an 18% reduction was achieved. This study concluded that reductions of 15 to 30% in average fuel consumption could be achieved "...by developing programmes aimed at improving drivers' awareness of the factors that influence fuel consumption as well as their performance."

Similar studies in the United States have demonstrated that fuel efficient driving strategies can improve average efficiencies by well over 10%. An early study by General Motors (Chang et al., 1976, p. 11) concluded that, "It is possible for individuals to reduce their fuel consumption in urban traffic by adopting effective driving patterns."

Drivers asked, without training, to "minimize fuel consumption" achieved 10.4% better fuel economy than those asked to "drive normally." Those requested to "use vigorous acceleration and deceleration," on the other hand, did 17.3% worse. A later study by GM (Chang and Herman, 1980) compared "hard," "moderate," and "gentle" driving with respect to average speed and acceleration and deceleration. Hard driving decreased average driving time by 9% as compared with moderate but increased fuel consumption 29%. Gentle driving increased driving time 11% and reduced fuel consumption by an equal percentage.

In a major, early study for the U.S. Department of Transportation, Claffey (1976) conducted field tests in upstate New York with 24 cars and 93 drivers to determine how the way people drive and care for their cars affects passenger car fuel consumption. On an urban driving route, Claffey first asked all drivers to drive "normally" (no attempt was made to control for the Hawthorne effect, the tendency for subjects in a test to alter their behavior simply because they know they are being tested). He then asked 8 drivers to keep their acceleration rates at 3.5 m/h/s or less, and deceleration rates at a maximum of 4.5 m/h/s. The average fuel economy improvement for these 8 drivers was 4.8%.

Other studies have also documented the fuel costs of too rapid acceleration. The Southern California Auto Club (1973) tested 20 1969-73 model year cars on an auto raceway. The cars were accelerated to 40 mph from a stop, and then cruised a quarter mile at 40. The results were interesting, in that they suggest a more severe penalty for "heavy" acceleration for small cars than for large cars (Table A.1).

Table A.1. Southern California Auto Club acceleration tests (change in MPG)

	Small cars <3000 lbs.	Medium cars 3000-4000 lbs.	Large cars >4000 lbs.
Easy	+7.8%	+12.5%	+16.1%
Moderate	-	-	-
Heavy	-15.4%	-11.1%	-9.4%

Similar results were obtained by the Environmental Protection Agency in combinations of dynamometer, test track, and computer simulation studies. Increasing acceleration rates above those specified for the EPA test cycles reduced MPG by 16.8%-34.8% on the city cycle, and 6.6%-15.6% on the highway cycle.

Test after test has clearly shown that excessive rates of acceleration reduce MPG. Unfortunately, there is no precise information about the "best" rate of acceleration. Studies have tended to characterize acceleration rates qualitatively, using such terms as hard, easy, brisk, or moderate. As a result, when it comes to teaching drivers how to drive efficiently, the instructions are equally vague. DECAT materials instruct drivers to accelerate "briskly and steadily." In his book The Whole Truth About Fuel Economy Driving, the best Roe (1975) can offer is "Accelerate smoothly." Claffey (1976) advises that "reduced acceleration and deceleration rates" will conserve fuel.

In a study sponsored by the DOE DECAT program, Hooker provided a definitive answer using advanced programming techniques and an empirically-based vehicle simulator - but for one car only: a 1979 Ford Fairmont. In two examples, accelerating to 55 km/h and 90 km/h, Hooker found that

moderate acceleration gave the best fuel economy. In the 55 km/h case, about 50% of available power should be used until third gear was reached, at which point only 25% of available power should be used (the % of available power used corresponds roughly to throttle position). In the 90 km/h case one needs to start at about 60% of available power and gradually taper off to about 40% at 90 km/h. In the respective cases a velocity of 48 km/h is reached in 10 and 8 seconds, respectively. More quantitative results like this are needed for different vehicle designs if we are to be able to make useful generalizations about the fuel efficient way to accelerate. Ultimately, what is needed is an in-vehicle feedback device to inform the driver about what acceleration is costing him.

DECAT also stresses obeying the 55 mph speed limit. To the list of reasons for obeying the speed limit, DECAT adds direct fuel cost savings to the driver. A study of 350 1965-77 model-year automobiles (Greene, 1981) showed an average decline in MPG of 10-13% with increased speed from 50 to 60 mph, and from 12-17% in going from 60 to 70 mph, depending on car size. A typical car probably consumes 10-15% more fuel at 65 than at 55 mph. For a 25 MPG car, this is a savings of about 2.5 gallons per hour of additional travel time. At $1.25/gal. this is not a high rate of pay, but it should help to convince drivers to obey the law, save lives, and conserve fuel.

One of the first studies to use vacuum gauges as driver aids was by General Motors (Chang et al., 1976). Like later studies, it found that simple gauges combined with very simple instructions on how to use them achieved perceptible, but very modest improvements in fuel economy. The

gauges were marked with green (high pressure), orange, and red regions. Drivers instructed to keep the gauge needle in the green region (this would require extremely slow acceleration) actually used 2% more fuel than drivers driving "normally with the traffic." Those told to keep the gauge in the green or orange region did 5.4% better than those driving normally. Claffey (1976) too, used simple vacuum gauges in fuel economy driving tests. Over his urban field test route, 46 drivers instructed to keep the vacuum guage above 10 inches of mercury achieved slightly less than a 1% reduction in fuel use over their previous "normal driving" runs.

Additional studies by the Department of Transportation using miles-per-gallon meters, as opposed to vacuum gauges produced similar results (DOT, 1976). A 1977 DOT study (Banowetz and Bintz, 1977) found that in a test of 140 drivers, all "motivated to save fuel," the 70 drivers with meters achieved 3% better fuel economy than those without, but the results were not statistically significant.

DOE's DECAT program also tested the effectiveness of vacuum gauges as driver feedback devices. Indeed, it was through early tests of this type that DOE became convinced of the effectiveness of driver training in improving MPG. The "Driver Aid and Education Test Project," (DOE, 1978) combined training and two types of vacuum gauges in a field test involving 435 vehicles. The fleet was divided into four treatment groups and a control group (Table A.2). In a before and after test, only those groups using dial-type vacuum guages did better than the control group. Those receiving some training and using dial gauges did

Table A.2. Driver Aid and Education Test Project resutls

	Before-after % change in MPG
1. Control	+1.6%
2. Piston-type gauge	-0.2%
3. Training	+1.1%
4. Dial gauge	+3.0%
5. Dial gauge and training	+5.5%

5.5% better, on average, than the control; those using gauges alone did 3.0% better.

Although there were some problems controlling for other factors, such as temperature and seasonal driving patterns, these results are generally consistent with those of other researchers.

Probably the most comprehensive study of fuel conservation feedback devices was carried out by Bendix Corporation (1982) for the DOE DECAT program. Bendix tested the ability of several combinations of feedback devices to improve MPG in combination with driver training. All devices improved efficiency, with a range of 2.4 to 8.8%. The most effective device combined instantaneous MPG displays with some sort of audible alarm to alert the driver when manifold vacuum dropped below a threshold (Table A.3). The Bendix study also produced a prototype design of an "ideal" feedback device. While this device needs to be reevaluated in light of continuing advances in microcomputer technology, it provides a useful starting point for future research.

Table A.3. Effect of feedback devices on fuel economy: Bendix study

	Baseline (no devices) ave. mpg	After training and with feedback devices ave. mpg	% change
Digital displays - vacuum threshold alarm	26.14	28.06	7.3%
Instantaneous MPG analog - vacuum threshold alarm	25.56	26.17	2.4%
Vacuum gauge - voice device	25.11	26.25	4.5%
Vacuum gauge - digital displays	24.97	26.27	5.2%
Instantaneous MPG analog - voice device	24.72	26.90	8.8%

Source: Bendix Corporation, 1982, p. 91.

A.2.1 DECAT and Safe Driving

The principles of efficient driving which DECAT espouses are also principles of safe driving. DECAT stresses: 1) being aware of traffic situations to be able to avoid sudden changes in momentum, 2) anticipating manoevers such as turns and stops, 3) developing the skills needed to accurately control the vehicle, and 4) developing the right attitudes for fuel efficient driving. Driver instruction researchers have identified the following 7 important psychological functions as important for safe driving (OECD, 1976):

1. perceptual scanning
2. identification

3. predicting
4. decision-making
5. motor skills and control of vehicle
6. knowledge
7. attitudes

Many of these are featured in DECAT training. The main part of this report proposes ways that safe driving principles and training can be purposefully incorporated into DECAT training.

A.2.2 Summary: Driver Behavior

Research to date has addressed primarily the effects of acceleration and deceleration on fuel economy. Fuel economy improvements on the order of 5-10% are obtainable using "good" versus "normal" acceleration habits. A key problem is the vagueness of our knowledge about what exactly constitutes optimal acceleration. At the present time we are limited to unclear, qualitative statements such as "brisk" or "moderate." Improving our understanding in this area is critical to developing a credible, scientific base for DECAT's curriculum.

More importantly, DECAT's driver training includes far more than acceleration and deceleration. A key element is anticipation of manoevers and traffic situations, which allows the conservation of momentum, thus reducing the need for acceleration and contributing to safe driving. Other important areas include idling, cornering, cruising, and hill climbing. These areas are even less well understood than acceleration and represent important topics for further research. Finally, DECAT training stresses obeying posted speed limits, for safety and fuel economy. DECAT teaches that 55 mph not only saves lives but money too.

Table A.4 presents a range of estimates of the potential for improving vehicle fuel economy through improved driving techniques. Wherever possible, estimates have been chosen which maintain the same average speed or travel time.

Table A.4. Estimates of fuel economy improvements possible via improved driving technique

Source	Potential improvement
1. TRRL (England, 1979)	+18.0%
2. Claffey (1976)	+4.8%[a]
3. Chang, et al. (1976)	+10.4%
4. Southern California Auto Club (1973)	+7.8-16.1%[a]
5. U.S. EPA (1980)	+6.6-34.8%[a]

[a]Includes acceleration strategies only.

In several cases only acceleration strategies were considered, thus greatly limiting the potential for improvement. Even so, available data suggest that 10% is probably a conservative estimate of the efficiency improvement achievable by a typical driver, in normal driving. Another significant element of the DECAT curriculum is vehicle maintenance, the subject of the following section.

A.3 VEHICLE MAINTENANCE AND FUEL ECONOMY

A.3.1 Vehicle Maintenance

The potential for improving fuel economy through maintenance depends entirely on the current state of the vehicle. Numerous studies, however, have demonstrated that fuel economy penalties for improper or inadequate maintenance can be substantial. An important part of the DECAT program is to inform operators about what aspects of car care are most important to maintaining optimal efficiency.

Perhaps the easiest single car care action a driver can take to improve his vehicle's efficiency is to keep its tires properly inflated. The EPA estimates the sensitivity of MPG to tire pressures at 0.55% per psi, assuming all tires equally inflated (EPA, 1980). Thus a vehicle with all four tires at 20 psi, which had a recommended maximum of 30 psi, would suffer a loss in MPG of 5.5%. Of course, the potential for improvement depends on the current state of underinflation in the actual fleet. Based on three major surveys, including a total of 16,000 vehicles, the EPA concluded,

> "If the underinflated tires were merely brought up to recommended pressure, their 3.4% shortfall would be eliminated, and fuel economy for the overall fleet would improve 2.3%." (EPA, 1980, pp. 179-180.)

Similar estimates are found in other sources. Claffey, for example, concluded that a 20% tire pressure reduction would produce a 4% increase in fuel use at 55 mph, and a 5.2% increase at 30 mph.

As is typical of car care actions, maintaining correct tire pressures also saves money by reducing wear and tear on vehicle components, and contributes to safe vehicle operation. The driver thus triples his benefits.

Using the right kind of tires is also important to fuel economy. Radial tires generally give better fuel economy than bias ply tires, although the size of the gain may vary from car to car (Falcon, 1981). Claffey found that radial versus bias ply tires saved 7% of fuel consumption at 30 mph. The EPA (1980), reviewing seven studies, found the average superiority of radial tires to be nearly 4% (Table A.5). In addition, radial tires pay for their extra cost because they last nearly twice as long.

Table A.5. Average MPG improvement for radial tires

Cycle	% MPG improvement
EPA City	+3.9%
EPA Highway	+3.4%
30 mph cruise	+4.5%
50 mph cruise	+4.1%

Rolling resistance is not only increased by poor tire design and underinflation, but also by misalignment and brake drag. There is very little data on the amount of excessive brake drag (OECD, 1981), however, the EPA has offered an estimate of the fuel economy penalty to the U.S. fleet of 0.5% to 1.0%. They add that they believe this figure to be conservative. Several studies have indicated that front wheel misalignment can have very significant MPG effects (e.g., Yurko, 1978; MVMA, 1973). An EPA study points to a DOT survey of 125,000 vehicles in five states, which found that 19% of all cars failed a front-end alignment test, and that 10% of all vehicles are probably operating under a 4% fuel economy penalty due to misaligned wheels (EPA, 1980).

All the factors mentioned which affect rolling resistance and MPG, are also important for safe operation of the vehicle. In general, they are also low-cost maintenance actions.

In recent years "fuel saver" lubricants have been introduced which have been proven to increase MPG (Naman, 1981; Coordinating Research Council, 1978, e.g.). An EPA study which surveyed the literature concluded that improvements ranged from 0 to 10%, but that an overall average of 3.4% was reasonable. It is not known exactly what market

share fuel saver oils currently have, but they are only available in multigrade oils which represented 40% of the market in 1976-77.

Finally, an improperly tuned vehicle wastes fuel, the amount depending entirely on the extent and nature of the problem. Table A.6 presents a summary of international studies cited by the OECD (1981). Claffey's (1976) study points out the fact that a tune-up is beneficial to fuel economy only when it is needed. Taking a random sample of 22 cars from the traffic stream, Claffey gave each one a tune-up, whether it needed it or not. The tune-up included plugs, points, condenser (these are not used on many new cars), air filter, dwell timing, vacuum advances, compression test, and, if needed, distributor parts and fuel system parts. As a result of the tune-up 8 vehicles' MPG improved, 12 remained the same, and 2 actually got worse. For those which improved, savings were as much as 16%.

Table A.6. Effect of improper tuning on MPG

Country	Spark plugs 1 in 4 miss.	Carburetor fuel mix.	Idle speed adjustment	Filters
England	5-15%	7-20%	3-8%	1-15%
U.S.A.	13-15%	11-20%	0-4%	
France		¦----- 7-8% ----¦		
Denmark		6%		
Sweeden		¦----- 4.3% ----¦		
Finland		¦----- 4.0% ----¦		

A.3.2 Summary: Vehicle Maintenance and Fuel Economy

Vehicle maintenance can improve fuel economy significantly, the size of the improvement depending on the size of the maintenance problem. The general rule that if it's working properly don't fix it certainly

applies here. Yet there is considerable empirical evidence that problems such as tire underinflation, wheel misalignment, failure to use fuel saving lubricants, and out-of-tune vehicles, are present in a large proportion of the vehicle fleet. The following table summarizes conclusions of the OECD (1981) and EPA studies on automobile fuel consumption with regard to the actual fuel savings potential of improved vehicle maintenance. The total in Table A.7 is calculated using the lowest value when a range is specified. The values also take into account the prevalence of maintenance problems in the vehicle fleet. Although some of these data are rather old (5-10 yrs.) and probably not precise, still they do give a general idea of the magnitude of energy savings achievable by the average of consumers through improved maintenance: about 10%.

Table A.7. Potential fleet MPG gain from improved vehicle maintenance

Problem	Efficiency impact (% change in MPG)
1. Correct tune	4.7%
2. Wheel alignment	0.4%
3. Brake drag	0.5-1.0%
4. Correct tire pressure	1.0%
5. Better lubricants	2.0-4.0%
6. Radial vs. bias tires	1.2% (3.7% per tire times 31% of tires nonradials)
TOTAL	10.1%

A.4 SUMMARY: THE EVIDENCE ON ENERGY SAVINGS FROM DRIVER ENERGY CONSERVATION

The DECAT program includes all four areas in which vehicle owners and operators can improve fuel economy:

1. energy efficient driving techniques,
2. maintenance for energy efficiency,
3. efficient vehicle usage (trip planning),
4. selection of an efficient vehicle.

A review of the available evidence indicates that each of the first two actions, independently, has the potential to save the average driver at least 10% of his fuel bill. There appears to be no quantitative information on the average energy savings potential of trip planning, but what is known about the inefficiency of short trips from a cold start suggests that significant savings are possible. Likewise, there are no known estimates of efficiency improvements possible through consumers making better use of available fuel economy information in making vehicle choices. Hypothetically, the potential exists to increase fuel economy by one half.

What the best evidence on potential fuel economy improvements clearly shows, is that the DECAT program goal of providing the average driver with information and training which can save him at least 10% in normal driving is readily achievable.

B.1. TRUCKS: DRIVER TRAINING, MAINTENANCE, AND EQUIPMENT

The DECAT-T course addresses the problem of improving truck operating efficiency. The course covers three basic subjects:

1. fuel efficient driving techniques,

2. maintenance for fuel efficiency,
3. selection of fuel efficient equipment.

The material taught by DECAT-T in each of these areas has received wide acceptance and been widely applied in the trucking industry. The success of DECAT-T methods have been documented by firms and government studies.

Fuel efficient driving techniques for trucks stress the following:

1. keeping within the legal speed limit (55 mph),
2. conserving momentum by anticipating manoevers and traffic situations,
3. retraining of drivers to avoid higher rpm's, and using progressive shifting (especially on vehicles with "fuel saver" diesel engines).

Numerous field tests and in-work experiences have shown that these techniques reduce truck fuel consumption significantly. Wiltshire (1981) reports two experimental test programs in which driver training and motivation was successful in reducing fuel consumption in truck fleets by 9-15%. In a test of the effect of rpm on fuel economy (Travis, 1981), a 50% loaded diesel truck obtained 13.86 MPG using a low rpm technique, but only 8.19 MPG using a high rpm driver option. The results were repeatable for different trucks, gasoline or deisel. Hunter (1981) reports a controlled test of four truck pairs for more than one year. Fuel economy improvements of 20-30% were demonstrated for use of a low rpm versus moderate rpm shift schedule, and 40-48% for low versus high rpm shift schedule. In actual operations, improvements attributed by trucking companies to driver training on the order of

10-25%, or more, are common (e.g., Millan, 1981; Heavy Duty Trucking, June 1984, and June 1983; Commercial Car Journal, November 1979, and September 1981; Fleet Owner Magazine, December 1981).

A study by Argonne National Laboratory (1982) concluded that improved driving practices could reduce truck fuel consumption by 12%. Significant savings were attributed to:

1. using progressive shifting,
2. keeping within the 55 mph speed limit,
3. eliminating excessive idling,
4. avoiding sudden stops and starts, by anticipating,
5. monitoring fuel use to provide feedback to drivers.

The same study estimated savings achievable by improved maintenance at 1-8%. It pointed out that maintenance of correct coolant temperatures (about 185°F) can save fuel. Each 9°F drop in coolant temperature cuts fuel efficiency by 1%. Maintenance of fuel pumps and injectors is critical to diesel engine fuel economy. Increasing fuel rail pressure (overfueling) and governor cut off speed (overspeeding) in order to obtain a 10% power increase can cost 15% in fuel use (DOT, 1981). Just as in automobiles, maintaining maximum fuel efficiency requires proper maintenance of tire pressures, use of radial rather than bias ply tires, proper brake adjustment, and wheel alignment (DOT and EPA, 1980).

Selecting appropriate truck equipment is another key factor in maximizing MPG. Table A.8 summarizes estimates, taken from the literature, of fuel economy improvements obtainable with equipment which is readily available and of proven effectiveness (Roberts and Greene, 1983). Use of fuel saving equipment reduces the truck's power require-

Table A.8. Current heavy truck fuel economy options with ranges of fuel savings estimates from the literature (Roberts and Greene, 1983)

Technology	Range of estimated fuel savings (%)
Diesel engine	30-55
Fan clutch	3-8
Fuel saver diesels	5-20
- direct injection	
- turbocharging	
- after cooling	
- low rpm	
- high torque rise	
Radial tires	3-10
Aerodynamic add-ons	3-10
- gap seals	
- side skirts	
- fairings	
- deflectors	
- air dams	
- boat tails	
- rounded corners	
- smooth skin	
Tag axle	2-5
Improved lubricants	1-2

ments, enabling additional savings to be realized by derating (reducing engine horsepower). Many of these devices have already received wide acceptance by the industry, largely due to the efforts of the former Joint Industry-Government Voluntary Truck and Bus Fuel Economy Program. For example, fuel economy diesel engines were installed on 69% of new

trucks over 33,000 lbs. gross vehicle weight (GVW) in 1983. Aerodynamic devices, however, were installed on only 33% of the larger trucks. Radial tires were specified for 82% of the 81,000 new trucks, of greater than 33,000 lb. GVW but less than 20% of the 77,000 new trucks between 10,000 and 33,000 lbs. GVW (Table A.9). The Motor Vehicle Manufacturers Assoc. (1985) estimates that increased use of such equipment was responsible for saving 2.4 billion gallons of diesel fuel in the U.S. in 1983 alone, and has saved a cumulative total of 13.8 billion gallons since 1974. A great deal has been achieved but a great deal remains to be done.

Voluntary fuel economy programs, including driver training, have been very well received by the trucking industry, especially the larger trucking firms which have the capability to perform cost-benefit analysis, conduct tests, maintain records, and even institute their own driver training and monitoring programs. On the other hand, independent truckers have been particularly hard to reach. A major challenge to the DECAT program lies in adapting their methods and devising strategies to reach independent truckers, small truck fleets, and government fleets.

Table A.9. Historical penetrations for fuel economy options available on class 8 (over 33,000 lbs GVWR) trucks (Roberts and Greene, 1983)

	Diesel	Economy diesel	Aerodynamic devices	Radial tires	Fan clutches	Tag axle	Road speed governors
1973	87.3	15.4	0.8	3.2	4.0		
1974	87.0	18.2	1.1	3.8	3.8		
1975	87.9	28.6	3.2	7.8	24.0		
1976	92.8	30.5	13.0	24.0	39.1		
1977	95.0	50.1	11.2	23.2	47.7		
1978	94.9	57.3	11.9	29.5	75.1		
1979	93.3	59.6	12.9	34.2	82.6		
1980	94.0	57.0	15.2	40.7	84.8		
1981	96.0	56.6	17.6	62.1	91.0		
1982	99.0	62.8	24.4	64.5	96.5	0.7	2.5
1983	99.3	68.7	33.4	81.7	96.0	0.3	3.5

Source: Fuel Economy News, Voluntary truck and bus fuel economy program, USDOT.

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