The Petroleum Challenge

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INTRODUCTION

More than 95 percent of all mechanically propelled transportation is fueled by petroleum. In the United States a significant proportion of the electricity used to propel trains, elevators, escalators, conveyor belts, forklift trucks, etc., is generated by turbines fueled by petroleum and natural gas. The feedstocks to produce epoxies and plastics come from the top of the barrel (and asphalt from the bottom) when it is not cracked to produce additional gasoline and other fuels.

As we learned in school, coal and oil were produced from vegetation subjected to high temperature and pressure over many eons. Produced from the sun's energy through the process of photosynthesis, coal and oil are two forms of solar energy. Since energy from the sun is necessary for the evaporation that later results in rain, and provides the forces which result in the high subterrain temperatures that produce geothermal power, all but nuclear energy appears to be solar energy. The solar energy arriving on the surface of this country every day is many times that used in our factories, vehicles, and homes. There is no energy shortage. There is a shortage of petroleum in the United States. In 1972, nearly one quarter of all petroleum was used for highway transportation in this country. Those concerned with highway transportation are therefore faced with the petroleum challenge.

The petroleum challenge is the challenge to develop the technology and procedures to provide the maximum transportation service with minimum petroleum, to develop additional transportation energy supplies, and nonpetroleum fuel for stationary uses.

There are a large number of immediate problems and a number of additional problems in the long run. How many of us have faced long lines to buy gasoline or have foregone a long auto trip due to the gasoline shortage? Many construction projects have been delayed for lack of diesel fuel or asphalt, and some because employees did not have the gasoline to drive to work.

Several aspects of the petroleum problem and proposals related to conservation are discussed which may be of interest to those concerned with road programs. These include: 1) financing, 2) conservation, 3) the road, 4) incentives, and 5) goals. As is often the case in times of change, some of these have merit while others are radical departures from traditional patterns. It is difficult to judge which have merit.

HIGHWAY FINANCING

To determine impacts on the Federal Highway Trust Fund, a check of possible impacts was made by the Highway Statistics Division based on the assumption that gasoline tax earnings, beginning with January 1974 and continuing to the end of the fund through September 1977, would be approximately at the annual rate experienced in 1968. This approximates a 30 percent cutback and was selected as an extreme or "worst" condition. The data are shown in Table 1. Diesel fuel tax revenue is expected to continue to increase, as are other excises, although at a reduced rate due to decreased wear and tear on tires and parts due to less travel and reduced speeds. A 22 percent reduction in revenue for the remaining years of the trust fund would result.

TABLE 1 ESTIMATED FEDERAL HIGHWAY TRUST FUND EARNINGS BY 1974-1978[1]

(Millions of dollars)

Fiscal Year	Net Gasoline	Diesel	Other Excises	Total
1974	3,300	337	1,400	5,037
1975	2,900	345	1,440	4,685
1976	2,900	355	1,480	4,735
1977	2,900	365	1,520	4,785
1978 (3 months)	730	110	380	1,220
Total	12,730	1,512	6,220	20,462

[1] It has been assumed that beginning with the second half of fiscal year 1974 gasoline tax earnings will be approximately the annual rate experienced in 1968. Other excises would be reduced accordingly. This analysis assumes no change in tax rates.

With a continuation of the existing annual $4.4 billion obligation level plus existing unpaid obligations an unexpended balance of about $1 billion could be expected at the close out on September 30, 1978.

Table 2 shows the effect of a 30 percent gasoline tax reduction on highway-user revenues for each state based on 1972 tax rates. Total revenues would be reduced to 88.3 percent by reduction in gasoline consumption to 70 percent of actual 1972 usage. Although the percentage reduction in state revenues is less severe than the percentage reduction in federal trust fund revenue, the impact on construction, particularly on new contract awards, will be extremely severe in many states. This is because maintenance and administrative costs continue to increase due to inflation, and because payments must be made to contractors working on previously awarded contracts. In most states project lettings are planned on the basis of anticipated revenue estimated on the basis of three to seven percent annual growth. Thus, a five to ten percent annual decrease can eliminate planned lettings and even require borrowing to make payments to contractors during the peak months at the end of the construction season.

Several states have introduced legislation to increase the gasoline tax. Another proposal is to impose an ad valorem tax which would be a fixed percentage of the selling price of motor fuel similar to a sales tax. This would result in additional revenue if the price increased. With increased gasoline prices, proposals to increase taxes are unpopular. Increases under consideration include 1.6 cents in Indiana, two cents in Maine to 11 cents, and one cent in South Dakota to eight cents. Massachusetts and Washington are considering a sales tax with revenue to the general fund. The seven states with a sales tax on gasoline are California, Georgia, Illinois, Indiana, Michigan, Mississippi, and New York with proceeds to the general fund.

CONSERVATION

Table 3 shows the influence which various changes in vehicle usage and characteristics have on fuel consumption.[1] Several types of changes are shown in column one with their percentage effects on fuel consumption shown in column two. Specific examples are given in column three and the resulting net decrease in the quantity and percentage of fuel consumed shown in column four. The relationships for passenger transportation are shown in Figure 1.

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[1] Table B-3 from "Example Computations and Sensitivity Analysis for Highway Energy Consumption," by A. French and R. W. Sherrer.

TABLE 2 THE EFFECT OF A 30 PERCENT REDUCTION IN HIGHWAY GASOLINE CONSUMPTION ON STATE REVENUES AVAILABLE FOR HIGHWAY EXPENDITURE

STATE	1972 REVENUES APPLICABLE TO HIGHWAYS			REVENUES ASSUMING A 30 PERCENT REDUCTION IN GASOLINE CONSUMPTION			
	GASOLINE TAX REVENUES	ALL OTHER REVENUES [1]	TOTAL	GASOLINE TAX REVENUES	ALL OTHER REVENUES [1]	TOTAL	PERCENT OF 1972 ACTUAL REVENUES
Alabama	131,515	170,534	302,049	92,060	170,534	262,594	66.9
Alaska	8,703	113,900	122,603	6,092	113,900	119,992	97.9
Arizona	72,029	118,807	190,836	50,420	118,807	169,227	88.7
Arkansas	79,386	94,470	178,856	55,570	94,470	150,040	86.3
California	719,600	810,410	1,530,010	503,720	810,410	1,314,130	85.9
Colorado	73,905	135,073	208,978	51,734	135,073	186,807	89.4
Connecticut	104,279	155,083	259,362	72,996	155,083	228,079	87.9
Delaware	16,241	52,295	68,536	11,368	52,295	63,663	92.9
Florida	279,365	262,402	541,767	195,556	262,402	457,958	84.5
Georgia	131,056	135,710	266,766	91,739	135,710	227,449	85.3
Hawaii	12,579	46,134	58,713	8,805	46,134	54,939	93.6
Idaho	32,847	63,965	96,312	22,993	63,965	86,958	89.8
Illinois	328,427	574,561	902,988	229,899	574,561	804,460	89.1
Indiana	208,903	220,350	429,253	146,232	220,350	366,582	85.4
Iowa	103,992	193,652	297,644	72,794	193,652	266,446	89.5
Kansas	77,435	123,095	200,530	54,205	123,095	177,300	88.4
Kentucky	125,752	239,139	364,891	88,026	239,139	327,165	89.7

TABLE 2 THE EFFECT OF A 30 PERCENT REDUCTION IN HIGHWAY GASOLINE CONSUMPTION ON STATE REVENUES AVAILABLE FOR HIGHWAY EXPENDITURE—(Continued)

STATE	1972 REVENUES APPLICABLE TO HIGHWAYS			REVENUES ASSUMING A 30 PERCENT REDUCTION IN GASOLINE CONSUMPTION			
	GASOLINE TAX REVENUES	ALL OTHER REVENUES[1]	TOTAL	GASOLINE TAX REVENUES	REVENUES OTHER ALL[1]	TOTAL	PERCENT ACTUAL 1972 OF REVENUES
Louisiana	129,241	205,972	335,213	90,469	205,972	296,441	88.4
Maine	42,467	66,093	108,560	29,727	66,093	95,820	88.3
Maryland	120,767	233,603	354,370	84,537	233,603	318,140	89.8
Massachusetts	166,372	180,538	346,910	116,460	180,538	296,998	85.6
Michigan	283,112	430,597	713,669	198,178	430,557	628,735	88.1
Minnesota	124,309	196,469	320,778	87,016	196,469	283,485	88.4
Mississippi	90,746	118,202	208,948	63,522	118,202	181,724	87.0
Missouri	135,411	207,992	343,403	94,788	207,992	302,780	88.2
Montana	28,177	100,775	128,952	19,724	100,775	120,499	93.4
Nebraska	67,081	85,372	152,453	46,957	85,372	132,329	86.3
Nevada	20,793	44,035	64,828	14,555	44,035	58,590	90.4
New Hampshire	34,031	54,763	88,794	23,822	54,763	78,585	88.5
New Jersey	159,152	399,448	558,600	111,406	399,448	510,854	91.5
New Mexico	38,531	87,168	125,699	26,972	87,168	114,140	90.3
New York	367,730	643,122	1,010,852	257,411	643,122	900,533	89.1
North Carolina	236,353	210,180	446,533	165,447	210,180	375,627	84.1
North Dakota	22,156	58,052	80,208	15,509	58,052	73,561	91.7

Ohio	319,893	449,330	769,223	223,925	449,330	673,255	87.5
Oklahoma	95,444	153,430	248,874	66,811	153,430	220,241	88.5
Oregon	65,069	198,733	263,802	45,548	198,733	244,281	92.6
Pennsylvania	362,071	525,694	887,765	253,450	525,694	779,144	87.8
Rhode Island	10,563	32,458	43,021	7,394	32,458	39,852	92.6
South Carolina	100,169	67,004	167,173	70,118	67,004	137,122	82.0
South Dakota	26,030	62,044	88,074	18,221	62,044	80,265	91.1
Tennessee	136,326	196,121	332,447	95,428	196,121	291,549	87.7
Texas	247,325	522,458	769,783	173,128	522,453	695,586	90.4
Utah	38,588	89,808	128,396	27,011	89,808	116,819	91.0
Vermont	20,194	50,093	70,287	14,135	50,093	64,223	91.4
Virginia	174,092	325,112	499,204	121,864	325,112	446,976	89.5
Washington	142,643	239,604	382,252	99,854	239,604	339,453	88.8
West Virginia	61,079	279,988	341,067	42,755	279,988	322,743	94.6
Wisconsin	132,146	145,265	277,411	92,502	145,265	237,767	85.7
Wyoming	18,340	61,193	79,533	12,838	61,193	74,031	93.1
Dist. of Col.	16,836	38,076	54,912	11,785	38,076	49,861	90.8
Total	6,539,256	10,268,332	16,807,588	4,577,476	10,268,332	14,845,803	88.3

[1] Includes diesel and other special fuel taxes, motor vehicle and motor carrier taxes, Highway Trust Funds, other federal funds, payments from local governments, tolls, state general fund appropriations, other state imposts, and various miscellaneous revenue.

Prepared by: Highway Statistics Division
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TABLE 3 SENSITIVITY OF HIGHWAY FUEL CONSUMPTION TO VARIOUS CHANGES IN USAGE AND VEHICLE CHARACTERISTIC

Change in Travel Characteristic or Relationship	Percentage Change in Total Highway Fuel Consumption Per One Percent Change in the Characteristic or Relationship Described in Column 1	Example: Type and Amount of Change[1]	Net Change in Fuel Consumption from Example in Column 3[2]
Shift auto travel to walk and bicycle	0.71	Shift 10 percent of auto person miles to walk and bicycle	Save 6,223 million gallons or 7.06 percent
Increase average miles per gallon of autos	0.64	Increase average for all auto travel from 13.63 mpg to 15.00 mpg or 10.05 percent	Save 5,683 million gallons or 6.45 percent
Increase average car occupancy—passenger miles per vehicle-mile	0.52	Increase occupancy from 2.2 to 3.0 passenger miles per vehicle mile or 36.4 percent	Save 16.6 billion gallons or 18.9 percent
Shift travel from autos to motorcycles	0.45	Shift 10 percent of auto person miles to motorcycles averaging 75 mpg	Save 3,957 million gallons or 4.49 percent
Shift auto travel to diesel bus transit	0.35	Shift 10 percent of auto passenger miles to diesel bus transit	Save 3,116 million gallons or 3.53 percent
Improve single unit truck fuel efficiency	0.15	Improve single unit truck fuel efficiency from 10.12 mpg to 13.0 mpg or 28.46 percent	Save 3,663 million gallons or 4.16 percent

Improve loading efficiency of single unit trucks	0.14	Improve loading efficiency for single unit trucks from 1.085 to 1.5 ton-miles per vehicle-mile or 38.25 percent	Save 4,573 million gallons or 5.19 percent
Improve truck combination fuel efficiency	0.08	Improve truck combination fuel efficiency from 4.81 mpg to 5.5 mpg or 14.35 percent	Save 1,028 million gallons or 1.17 percent
Improve loading efficiency of truck combinations	0.07	Improve loading efficiency of truck combination from 9.209 to 12.00 ton-miles per vehicle mile or 30.31 percent	Save 1,907 million gallons or 2.16 percent
Improve transit bus fuel efficiency	0.004	Improve transit bus fuel efficiency from 3.90 mpg to 5.00 mpg or 28.2 percent	Save 99 million gallons or 0.11 percent
Shift school bus riders to walk and bicycle	0.003	Shift 10 percent of school bus person miles to walk and bicycle	Save 29 million gallons or 0.03 percent

[1] Initial value in this column are from Table 4.

[2] The percentage changes in fuel consumption are calculated on the 88,122 million total gallons of fuel consumed shown on Table 4.

As Table 3 shows, fuel consumption, as might be expected, is most sensitive to a shift from auto travel to the nonfuel-consuming modes, walking and bicycling. A shift of one percent from auto to walk, and bicycling would result in a 0.71 percent fuel saving. Next, an increase in the average miles per gallon for autos results in a 0.64 percent fuel saving for one percent improvement, an increase in average car occupancy (0.52) and a shift of travel from auto to motorcycle (0.45), in that order. Although still within an effective range, fuel consumption is somewhat less sensitive to shifts in travel mode from auto to diesel transit bus, saving .35 percent for every one percent shift. While less influential, improved single-unit truck fuel (0.15) and loading efficiency (0.14) are other possibilities for reducing fuel consumption. Improvements in the loading and fuel consumption rates of truck combinations (0.07) and improved efficiency of school buses (0.003) have negligible effect.

The bottom bar of Figure 1 shows the equivalent passenger miles per gallon (pmpg) for the Bay Area Transit System when in full operation with projected patronage if all electricity was generated from petroleum. This provides a basis for comparison. The values used in Figure 1 are typical for various types of operation.

A typical transit bus transports from 10 to 15 passenger-miles per vehicle-mile when all deadheading and low occupancy off-peak travel is included. This results in 40-60 pmpg which is equivalent to typical

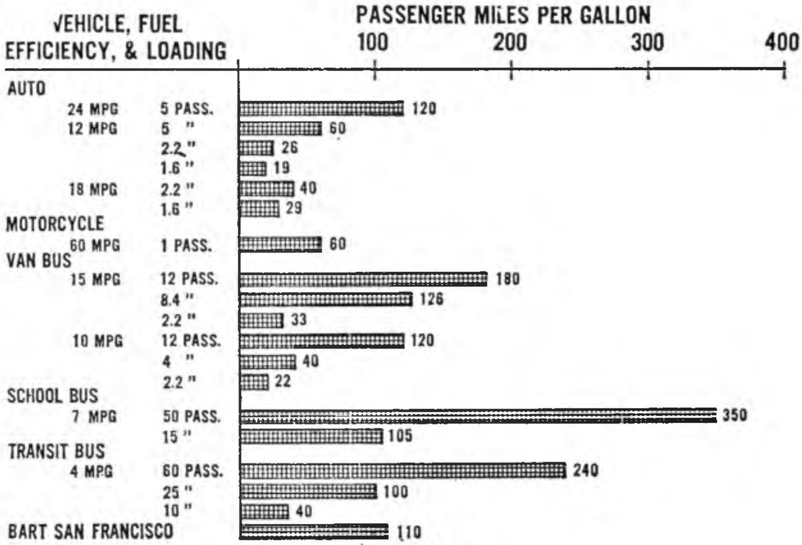

Figure 1

intercity auto travel at 18 mpg and 2.2 passenger-miles per vehicle-mile. For the peak hour line-haul portion of a bus route with standees, an efficiency of 240 pmpg can be achieved. This completely excludes the deadheading. The 25 pmpg is typical of dedicated bus lane express service where frequent stops are eliminated. Thus 100-110 pmpg appears to be a realistic maximum efficiency for transit operation, with 40 to 60 pmpg a more typical range.

A number of employers have arranged to have a school-type bus operated from a large apartment complex or residential subdivision to the parking area of a large employment center. With a full load and virtually no deadheading, 350 pmpg could be achieved.

Van-buspools carrying eight to 12 passengers with zero deadheading can achieve up to 180 pmpg. For motorcycles typical efficiency is 60 pmpg, and even higher efficiencies are possible with some machines.

The auto can also achieve high pmpg efficiencies through carpooling, careful operation to achieve high mpg, and shifts to highly efficient vehicles. A five-person carpool in a 24 mpg auto is hard to beat at 120 pmpg. This is apparently approached by some intermediate size cars at a steady 50 mph using the dedicated bus and carpool lanes of the Shirley Highway in the Virginia suburbs of Washington, D.C.

The immediate concern involves periods ranging from the next six months to the next one, five, ten and 20 years. Oil refineries require three or four years to build. Refineries now under construction to serve the United States market are expected to add about ten percent to capacity by 1976 or 1977, but at present rates of five percent or more annual growth through 1972, potential demand may increase by 15 or 20 percent in the same period. Additional refined products could be imported at much higher prices than is paid for oil.

In any case, either travel growth must be reduced, or fuel efficiency must be improved. It appears that both are occurring. Preliminary data show 1973 highway travel and fuel consumption increases are below four percent which is well below the rate of increase in 1972. A *decrease* of two percent or more is indicated for December 1973. The sale of high mpg cars increased by 24 percent compared to 13 percent for other cars in 1973. For the 1975 model year it appears that domestic production of small cars will approach or even exceed five million based on announced production changes.

THE ROAD

Grades, congestion, and stops all increase fuel comsumption and reduce mpg efficiency. Figure 2 shows that an eight percent grade will

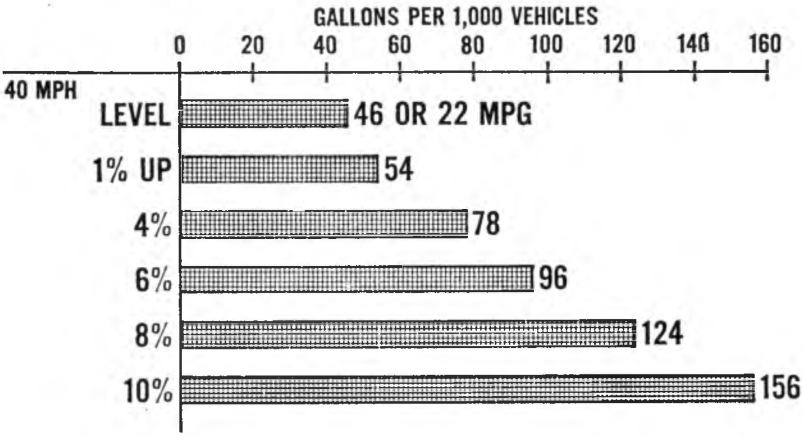

Figure 2

result in nearly three times as much fuel consumption as a level road section (16).[2] On a one percent upgrade speeds of 70 mph require nearly 40 percent more fuel than at 40 mph as shown in Figure 3. Figure 4 shows the effect of stops. At two stops per mile, 56 percent more fuel is required than at a steady 40 mph. Even poor pavement can

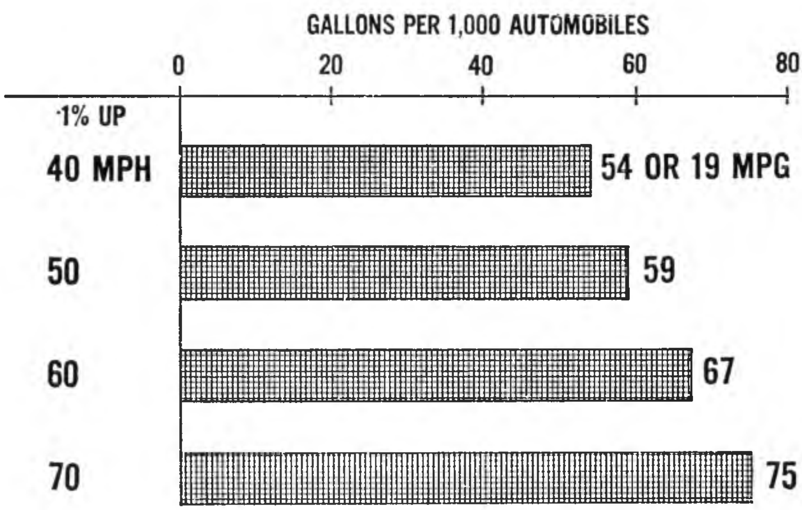

Figure 3

[2] Fuel consumption estimates are based on values from P. J. Claffey, "Running Costs of Motor Vehicles as Affected by Road Design and Traffic," *National Cooperative Highway Research Program Report,* No. 111, 1971.

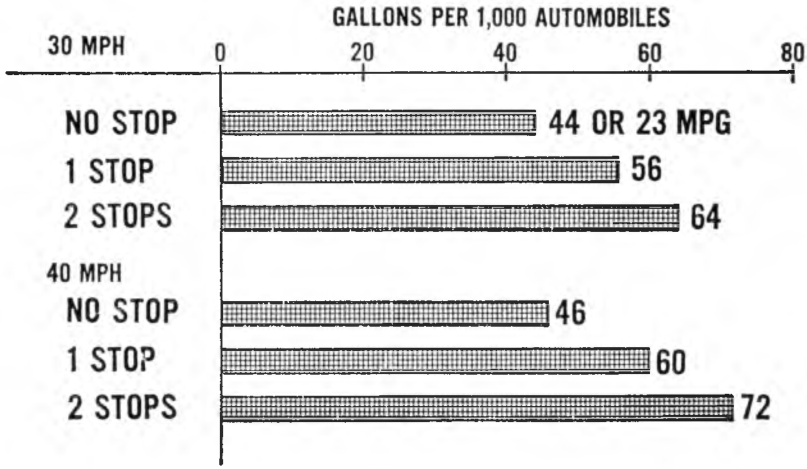

Figure 4

penalize fuel consumption on the order of 25 percent as shown in Figure 5. Where the proportions of tractor semitrailers are substantial, even greater savings will result from highway improvements. Figure 6 shows that for the comparable adverse road or traffic conditions, large trucks may consume four to five times as much fuel as automobiles. Thus, road sections with high traffic volumes and high truck percentages should be checked to eliminate unnecessary grades and stop and go driving.

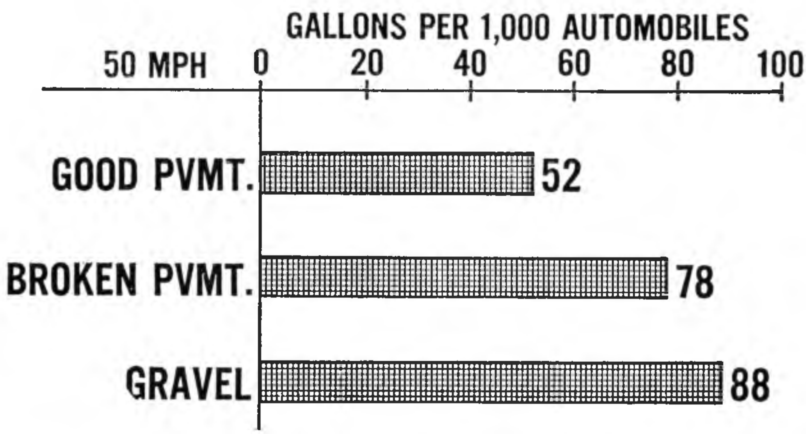

Figure 5

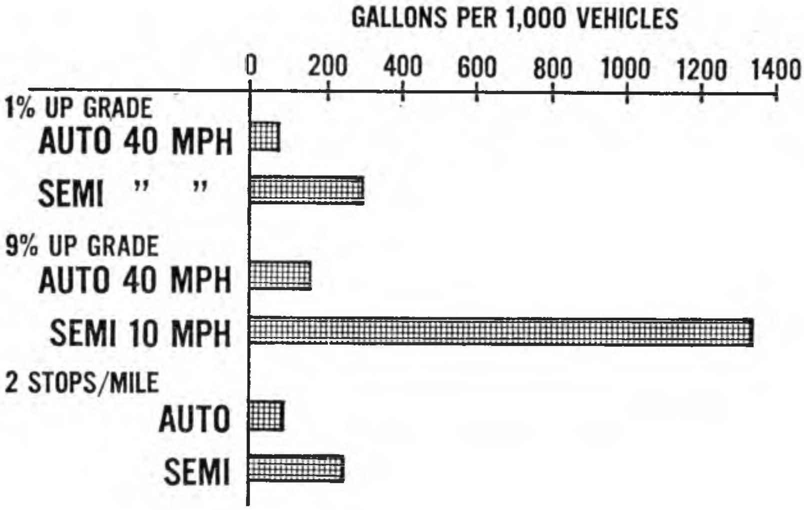

Figure 6

INCENTIVES

The automotive engineers know how to build more fuel efficient vehicles and the highway engineers can build better roads. Coal can be mined and converted, if necessary, to gas or synthetic gasoline or diesel fuel. All these things require large investments. To justify the investments and provide a return to the investors and to the highway user there must be assurance that these actions will provide a lasting benefit. Long-term policies must be established to proceed from "wait and see" to vigorous action.

When a two-hour wait is required to obtain a tank full of gasoline it is of greater advantage to many drivers to have a tank that will go 400 miles between fills at 10 mpg than a tank that will go only 200 miles between fills at 25 mpg.

The driver who is willing to change vacation plans, buy a smaller car, or bicycle to the bus stop may change his mind when he realizes that other users do not intend to conserve gasoline and because of their business or by other methods can obtain all the motor fuel they desire. One alternative is to allow prices to rise to dampen demand. Another is so-called "white market" rationing.

Various estimates of the price increases required to reduce demand by 10 to 20 percent indicate that increases to a price between $1 and $2 per gallon would be required to achieve the necessary reduction in demand.

The "white market" rationing procedure in its grandest form provided that all petroleum, or even all energy, would be rationed by negotiable coupons. Under these theoretical concepts each citizen would be assigned a ration that would be his monthly or annual share of the nation's fuel on a per capita basis. He would then exchange these coupons when he purchased gasoline, paid his electric bill, or made other direct purchases of petroleum produced energy, fuel, or other petroleum products. Industry, and business would purchase necessary coupons from employees, individuals, or through a market system. Energy values could also be assigned to products so that purchasers would exchange energy coupons as well as dollars so that the energy credits would go to the producer in this way also.

As proposed for petroleum the coupons would be used for private motor gasoline only, and coupons would be distributed to each licensed driver. Diesel fuel would be allocated based on various categories of need as would gasoline for business purposes. The private driver would then have the incentive to conserve his fuel so that he would not need to purchase additional coupons or so that he could sell his excess business. Users would be primarily concerned with negotiating for allotments. It has been suggested that standards of productivity be set for major uses, and requirements above these amounts would require purchase of additional coupons.

Another proposal is a heavy energy tax to be phased in over a period of years to replace state and federal income taxes and the local sales tax. While it has limited acceptance, proponents believe that this would be less regressive than the present tax structure, reducing the share of the total load carried by the poor, and it would provide an awareness and incentive for energy conservation. This would result in a tax on a gallon of heating fuel, gasoline or diesel fuel of 50 cents to $1.50 depending on whether all energy was taxed at an equal rate or only petroleum, and whether unemployment insurance and similar imposts are included. At a rate of $1 per gallon on the six billion barrels (42 gallons per barrel) of petroleum consumed in 1972, total revenue would have been over $250 billion. This compares to total estimated tax revenues (excluding unemployment insurance, etc.) collected by all levels of government amounting to $260 billion in that year.

An excise tax on petroleum using vehicles and equipment in relation to efficiency has been proposed as another means of providing manufacturers with a clear set of goals and to discourage purchase of inefficient equipment. An example related to automobiles and trucks will serve to explain the concept. For 1974 models there might be a onetime excise tax of $10 for each mile per gallon below 15 mpg. Thus the purchase of a new car achieving 15 mpg or better would require no tax payment, but there would be a $50 tax on a 1974 vehicle achieving 10 mpg. Each year the rate might be increased by $10 and the miles per gallon might be raised by 1 mpg. Thus by 1979, a 10-mpg car would be assessed $500, a 15-mpg car $250, while a 20-mpg car would not be subject to tax. By 1984, the tax would be $100 for each mpg below 30 mpg, and some reappraisal and adjustments would be made.

A legislative proposal in Vermont would impose an annual tax of $60 on vehicles achieving over 25 mpg to $350 on vehicles achieving less than 5 mpg. Thus, the same principle could be applied on an annual basis to encourage the earlier scrapping of the inefficient vehicles.

For construction equipment productivity might be in terms of drawbar horsepower per pound of fuel. For stationary equipment performance might be in terms of kwh per gallon, cubic feet pumped per gallon of fuel or a range of brake horsepower and torque outputs.

It would be important to establish realistic performance testing procedures so that designs to achieve good test results would also achieve comparable fuel efficiency after five or ten years of operation in all types of service. Some measure of vehicle capacity in seats or tons would be desirable. Attractive features of this proposal are the explicit long-term goals, and the relatively moderate costs to purchasers during the first years of application.

Since transportation is highly dependent on petroleum, it is important that nontransportation petroleum uses are monitored closely. It has been suggested that this might require performance standards for heating applications and taxes on stationary uses at the same rate as on transportation uses to encourage conversion to nonpetroleum fuels.

GOALS

The president has set the goal of energy self-sufficiency by 1980. There is no doubt that this is technically feasible with limited impact on transportation measured in passenger-miles and ton-miles. Autos are presently available which achieve double the national average of 13.5 mpg. Truck productivity in ton-miles per gallon (tmpg) can be increased by accelerated shifts to diesel, particularly by the single-unit trucks which account for 72 percent of truck fuel consumption. It has been proposed that the tmpg for large truck combinations can be improved by increases in length to permit greater loads while minimizing increases in pavement and bridge stresses. Loading factors for buses and passenger cars can be improved, and trips shifted to more fuel efficient modes.

With all of these improvements to transportation efficiency it has been estimated that the passenger-miles and ton-miles transported by highway in 1969 could be doubled, but require no more fuel than was consumed in 1972.[3]

With a substained effort, the goal of energy self-sufficiency in the United States can be achieved.

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[3] A. French, R. W. Sherrer, "Example Computations and Sensitivity Analysis for Highway Energy Consumption," FHWA Notice, February 28, 1973.