Transportation Energy Outlook Under Conditions of Persistently Low Petroleum Prices

MARIANNE MILLAR MINTZ, MARGARET SINGH, ANANT VYAS, AND LARRY JOHNSON

In much the same way that rising oil prices in the 1970s profoundly influenced petroleum production and consumption, an era of persistently low prices will have far-reaching consequences for petroleum supply and demand. Many of those consequences are indirect and will not be widely understood for some time; others are more clear-cut. In this paper, some of the anticipated consequences will be explored, including revised estimates of domestic petroleum reserves, production, and consumption, as well as oil imports. The focus is on transportation, the largest consumer of petroleum products and the most petroleum-dependent sector of the U.S. economy, and the conclusion is that persistently low oil prices will result in a significant decline in domestic oil production, a modest increase in petroleum consumption overall and in transportation (primarily due to reduced fuel efficiency in the vehicle fleet), and a substantial increase in our import dependence and vulnerability to supply interruptions and price shocks. Together, these effects increase the need for improved fuel efficiency and fuel flexibility, yet reduce the market incentive to develop and introduce new fuel-saving echnologies.

Few would argue that oil price forecasting is a risky endeavor. After the second price shock, most forecasters believed that the Organization of Petroleum Exporting Countries (OPEC) would successfully manipulate world oil prices for the foreseeable future, constraining production by both political and physical means. According to that logic, the OPEC cartel would only supply the marginal barrel at the "right" price, and real oil prices would continue their inexorable rise. By 1983, however, the combined effects of conservation, fuel switching, a world recession, and new non-OPEC supplies brought on a striking reversal in actual and predicted oil prices. While demand remained slack and crude prices hovered around $29 per barrel (bbl), forecasts became more demand driven. While prices were still expected to resume an upward path, the timing and slope of that trajectory became increasingly dependent on assumptions about world economic growth and exchange rates, as well as such supply-side factors as non-OPEC oil production and the development and market penetration of non-oil energy supplies.

To a certain extent, the oil price forecasts produced in 1983–1985 supplemented "OPEC-watching" with basic economics. These forecasts, characterized by the expectation that real prices would remain flat or decline slightly in the near term and then rise at annual rates of 1 to 3 percent, differed mainly in the timing of the price upswing *(1)*. The turning point, which was largely a function of when the forecast was generated, was placed variously between 1986 and 1992 [*1–3*; see also the *Annual Energy of Outlook*, U.S. Department of Energy, Report DOE/EIA-0383(83), May 1983 and later editions]. Thus crude oil prices were projected to range from $37 to $49/bbl (in 1985 dollars) in 1990, rising to about $55/bbl in 1995 and $65/bbl in 2000.

In retrospect, it is clear that the forecasts underestimated both the magnitude of the production surplus and Saudi Arabia's commitment to maintaining its oil revenues. Not until prices plunged below $14/bbl in early 1986 did a new round of postcollapse forecasts begin. While it is still too early to verify general trends from this new generation of forecasts, the peaking of non-OPEC oil production and the continued sluggishness in world demand appear to be major considerations. Thus prices are now expected to remain in the $15–20/bbl range for the near term and to rise gradually over the longer term as low levels of investment in nonpetroleum (alternative) energy and non-OPEC oil production increase U.S. dependence on OPEC supplies. The new forcests, unlike the 1983–1985 round of price forecasts, see declining supply (not rising demand) as the major impetus for eventual price growth.

Figure 1 shows the difference between pre- and postcollapse price expectations by contrasting the spring 1984 and autumn 1986 projections of world oil prices published by Data

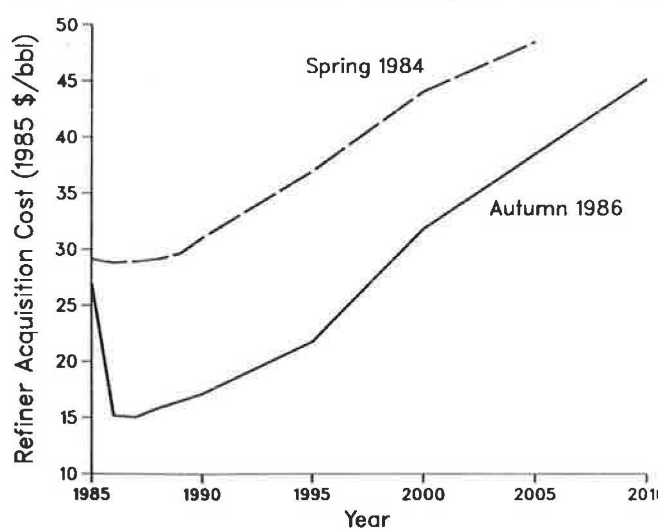

FIGURE 1 DRI oil price forecasts, 1984 versus 1986 [adapted from the *DRI Energy Review (4, 5)*].

Energy and Environmental Systems Division, Center for Transportation Research, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Ill. 60439.

Resources, Inc. (DRI) *(4, 5)*. The decline is particularly dramatic over the next decade, forcing analysts to reevaluate their forecasts of domestic and world consumption, production, and imports. The relevant aspects of that reevaluation will be briefly summarized here with particular emphasis on the impact of persistently low oil prices on the transportation sector and the outlook for new vehicles and fuels.

PETROLEUM CONSUMPTION, PRODUCTION, AND IMPORTS IN AN ERA OF LOW OIL PRICES

Petroleum Consumption

While lower oil prices will not bring commensurate increases in petroleum consumption, they will significantly affect demand. In a recent survey of representatives of industry, utilities, government, consulting firms, and the financial community, the National Petroleum Council (NPC) estimated that crude oil prices of $21 versus $36/bbl (1986 dollars) in the year 2000 would increase U.S. petroleum demand by 2.5 million (2.5×10^6) bbl/day (about 14 percent) *(6)*. Similarly, the Energy Information Administration (EIA) within the U.S. Department of Energy has estimated that a $10 reduction in crude oil prices (from $30 to $20/bbl) will increase 1995 U.S. oil consumption by 1.5×10^6 bbl/day (9 percent) *(7)*.

Frequently, however, revised economic forecasts obscure much of the impact of falling prices. For example, the DRI 1986 projection for U.S. petroleum consumption in 2000 is nearly equivalent to the value in the DRI 1984 forecast, despite the price decline mentioned earlier (Figure 2) *(4, 5)*. The similarity is due to a dramatic reduction in DRI's near-term industrial production forecast. Conoco's 1986 forecast also shows considerably less growth in oil consumption than price effects would otherwise suggest *(8)*. Conoco attributes its results to assumed declines in energy intensity from (a) new capital equipment and structures that require less energy than the existing stock, (b) increased cogeneration, and (c) a continuing shift in the economy toward less energy-intensive services and light manufacturing.

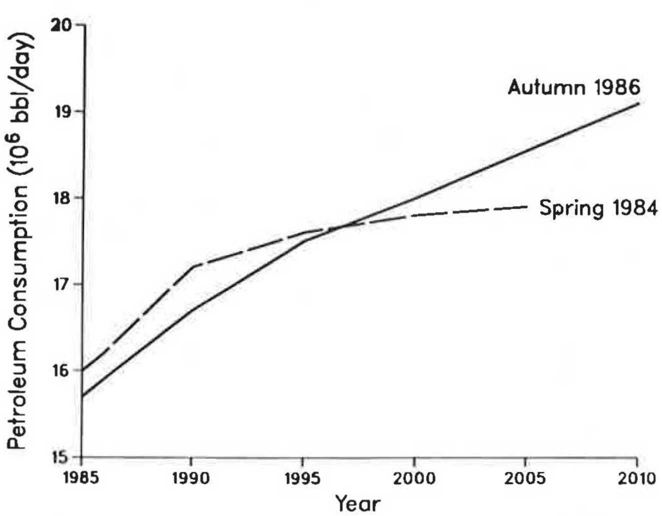

FIGURE 2 DRI forecasts of U.S. petroleum consumption, 1984 versus 1986 [adapted from the *DRI Energy Review* *(4, 5)*].

Persistently low oil prices are expected to have a much greater effect on oil demand outside the United States. While EIA predicts a 9 percent increase in U.S. demand, its Oil Market Simulation Model forecasts an increase of 9 to 13 × 106 bbl/day in 1995 world oil demand (20 to 28 percent) because of a $10 reduction in crude oil prices *(7)*.

Petroleum Production

On a percentage basis, lower prices are likely to have a far greater effect on production than on consumption. The United States is already a relatively high-cost producer, and much of its oil comes from low-volume stripper wells, many of which are becoming uneconomical at current oil prices. Further, the United States accounts for only 4 percent of world crude oil reserves, and despite dramatic increases in drilling after the price shocks of the 1970s, reserve additions have barely offset production in recent years *(9, 10)*. As shown in Figure 3, no giant domestic fields have been discovered since 1970, and recent drilling off the California and Alaska coasts has yielded several highly publicized disappointments *(6, 11)*. Because of declining prices, exploration has been drastically cut, and drilling has virtually stopped in many areas *(6, 12*; see also *Rotary Rigs Running, by State*, Hughes Tool Co., Houston, Texas; various issues). Between 1981 and mid-1986, domestic drilling—as measured by the average number of active rotary rigs—plummeted from a high of 3,970 to about 700 *(11)*. The data in Table 1 indicate the decline since 1983. Note that drilling in 1986 declined more sharply in the United States than in any other world region.

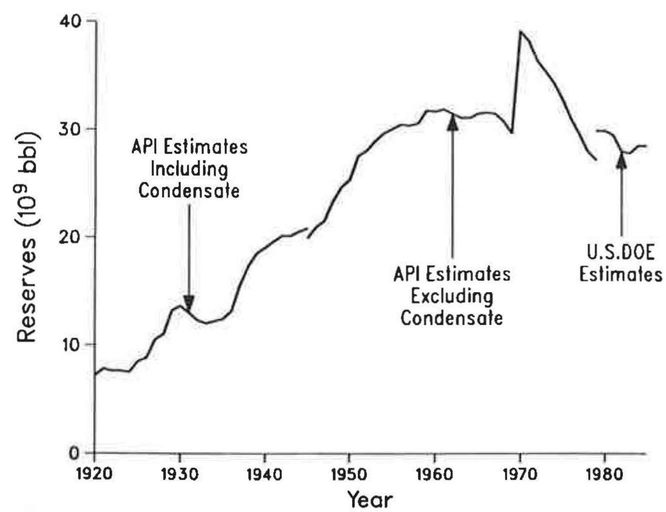

FIGURE 3 Estimates of U.S. crude oil reserves. Condensate is included in estimates until 1945 [adapted from *Twentieth Century Petroleum Statistics 1982 (10)* for pre-1980 estimates and from *Annual Energy Review 1985 (12)*].

As shown in Figure 4, U.S. oil exploration is particularly sensitive to crude oil prices. According to a recent NPC survey of members of the Independent Petroleum Association of America and the Society of Earth Scientists, drilling could decline by 85 percent (i.e., to fewer than 300 active rigs) by 1990 if crude oil prices remain at current levels *(6)*.

TABLE 1 AVERAGE NUMBER OF ACTIVE ROTARY DRILLING RIGS BY WORLD REGION, 1983–1986 *(11)*

Region	1983	1984	1985	1986 First Half	1986 June
United States	2233 (-28)	2428 (9)	1970 (-19)	1131 (-44)	705
Other Developed Countries					
Canada	203 (2)	257 (29)	313 (22)	235 (-20)	64
Western Europe	184 (-21)	203 (10)	231 (14)	218 (-4)	179
South Pacific	38 (-18)	37 (3)	36 (-3)	25 (-30)	17
Non-OPEC Developing Countries					
Middle East	59 (18)	71 (20)	77 (8)	84 (14)	78
Africa	47 (-19)	36 (-23)	36 (0)	24 (-33)	21
Far East[a]	187 (-2)	175 (-6)	181 (3)	165 (-9)	160
OPEC	802 (NA)	716 (-11)	729 (2)	669 (-8)	649
Total Noncommunist World	3723 (-22)	3923 (5)	3573 (-9)	2551 (-29)	1873

[a]Includes China.

Note: Numbers in parentheses are percent change from previous year.

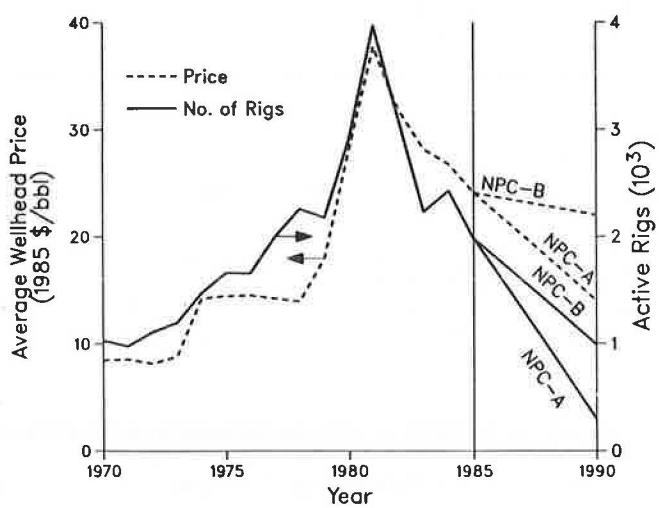

FIGURE 4 Crude oil price and drilling rig activity [adapted from various sources *(6, 12)*].

Similarly, the American Petroleum Institute (API) estimates 1991 drilling declines of 60 percent for $15/bbl crude oil and 80 percent for $10/bbl crude oil *(15)*.

Because it takes several years for economic quantities of crude oil to begin flowing from newly discovered reserves, such reductions have little impact on current domestic production, but they do have an increasingly negative impact on long-term production *(8, 14)*. According to the NPC survey discussed previously, if prices drop from $36 to $21/bbl, domestic production could decline by 30 percent (nearly 2×10^6 bbl day) in the year 2000 *(6)*. DRI and EIA forecast similar declines *(5, 7, 15)*.

Imports

Table 2 summarizes the effect of persistently low oil prices on import dependence, as well as on domestic drilling activity, production, and consumption. Over time, lower prices reduce

TABLE 2 OIL CONSUMPTION, PRODUCTION, AND IMPORT SHARES UNDER ALTERNATIVE PRICE ASSUMPTIONS, 1985–2000 *(5, 9–10, 15, 17, 21)*

Parameter	1985	1990	1995	2000
Crude Oil Price (1985 $)				
EIA	27	17-27[a]	20-30	NA[b]
DRI	27	17-31	22-37	32-44
NPC	27	14-22	17-28	21-36
API	27	15-28[c]	-	NA
Domestic Drilling Index				
EIA[d]	1.0	0.58-0.80	0.56-0.86	NA
NPC[e]	1.0	0.15-0.50	NA	NA
API[e]	1.0	0.4-1.0	NA	NA
Oil Consumption (10^6 bbl/day)				
EIA	15.7	17.1-16.1	18.2-16.6	NA
DRI	15.7	16.7-17.2	17.5-17.6	18.0-17.8
NPC	15.7	17.6-16.3	19.0-17.0	19.9-17.4
Domestic Production[f] (10^6 bbl/day)				
EIA	8.9	7.2-8.1	5.0-6.5	NA
DRI	9.0	7.9-8.5	6.4-8.2	5.6-8.0
NPC	8.9	7.1-8.0	5.7-7.0	4.5-6.4
Imports (10^6 bbl/day)				
EIA	4.3	7.4-5.8	11.0-7.8	NA
DRI	4.2	7.0-6.6	9.5-7.4	10.9-8.1
NPC	4.3	8.4-6.2	11.4-7.9	13.6-9.1
Import Share of Total Supply (%)				
EIA	27	43-36	60-47	NA
DRI	27	42-39	54-42	60-46
NPC	27	48-38	60-46	68-52

[a]First value in range refers to source's lower-price case, second value to source's higher-price case.

[b]NA = not applicable.

[c]1991.

[d]Indexed to 1985 total oil and gas footage drilled.

[e]Indexed to 1985 count of average active rotary rigs.

[f]Excluding natural-gas liquids.

Note: EIA = Energy Information Administration; DRI = Data Resources, Inc.; NPC = National Petroleum Council; API = American Petroleum Institute.

domestic production and encourage growth in oil demand. Clearly, this increases dependence on imported oil.

From a macroeconomic standpoint, increased oil imports can have either positive or negative effects, depending on whether they stimulate or reduce economic growth. In the near term, increased imports of lower-priced oil increase economic growth *(5, 15)*. In the longer term, low prices have mixed effects. Their impact on U.S. oil import expenditures is illustrated in Figure 5. On the basis of crude oil and refined product prices and import quantities presented in the most recent DRI forecast, Figure 5 shows import expenditures declining through the late 1980s and staying well below historical levels through the mid-1990s because sharply lower prices more than offset increased quantities, thereby producing a net benefit to the U.S. economy. By 2000, however, the combination of greater quantities, rising prices, and relatively more valuable refined products constituting a larger share of import quantities results in higher import expenditures in the lower-price (1986) case. (In the 1986 forecast the share of refined products rises from about one-third to more than one-half of petroleum import volumes by 1995.)

Increased oil imports also pose serious strategic implications. In 1983–1985, most forecasts estimated that U.S. petroleum imports in the year 2000 would range from 40 to 50 percent of supply, a share roughly comparable to that prevailing in the late 1970s. Since the price collapse, import share forecasts have been revised upward to 60 percent or more of

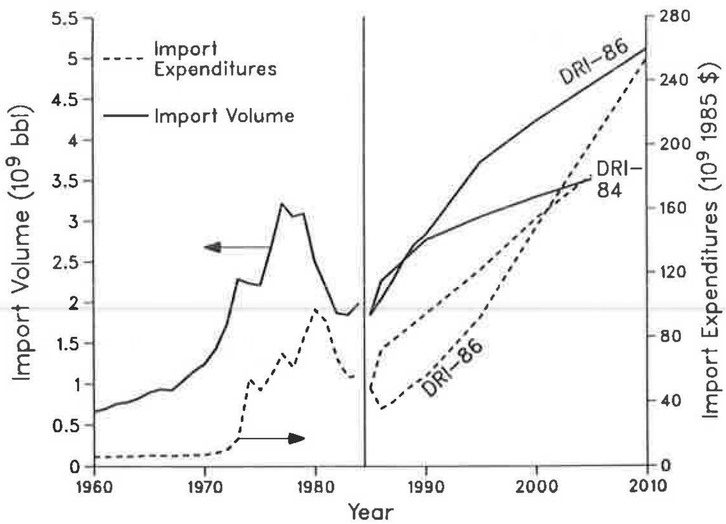

FIGURE 5 U.S. oil imports and oil import expenditures [adapted from various sources (4, 5, 12)].

U.S. petroleum supply in 2000. Such levels of import dependence significantly increase U.S. vulnerability to supply disruptions *(6, 8, 16, 17)*. Further, because 55 percent of the world's proven crude oil reserves and the bulk of surplus production capacity are located in the Middle East, U.S. import dependence will become increasingly concentrated on that region.

As the most petroleum-dependent demand sector, transportation is particularly at risk from supply disruptions. The dramatic price runups of the 1970s prompted large-scale shifts from petroleum to coal and nuclear fuels for power generation and to electricity for industrial process heat and for residential and commercial space conditioning *(12)*. Because many conversions (particularly by electric utilities) retained a multifuel capability, much of the price-induced increase in petroleum use in response to falling oil prices may come from a steady shift back to oil by fuel-flexible users. In the short run, this additional demand could compete with transportation for the marginal barrel in a sudden supply disruption, thereby further exacerbating the impact.

Analysts agree that the degree of U.S. vulnerability to possible oil price shocks and supply shortages depends on such factors as (a) level of domestic oil production, (b) size and accessibility of the Strategic Petroleum Reserve (SPR) and other surge production capability, (c) stability and diversity of U.S. energy sources, and (d) availability of alternative fuels and the technologies to use them. In the past decade, rising prices made it economically feasible to drill in marginal, geologically difficult or environmentally hostile areas, to devote substantial resources to R&D on enhanced recovery techniques and alternative fuels, and to maintain marginally productive stripper wells. Despite these significant efforts, no breakthroughs have dramatically increased U.S. reserves (either by new discoveries or enhanced productivity of existing wells) or made alternative fuels technically or economically competitive with petroleum. Without such breakthroughs, the United States is likely to be just as vulnerable to supply disruptions in the future as it was in the past. With increased consumption in response to persistently low oil prices, the issue of vulnerability, particularly for such oil-dependent sectors as transportation, becomes especially critical.

THE TRANSPORTATION SECTOR IN AN ERA OF LOW OIL PRICES

In 1985 the transportation sector accounted for 63 percent of U.S. petroleum consumption *(3)*. Unlike other sectors, in which relative prices influence fuel-switching decisions, transportation has no viable fuel flexibility in the near term. Thus the rising prices of the past decade did not promote significant fuel shifts. They did, however, encourage motorists to purchase vehicles that were more fuel efficient and to adopt various conservation practices. Although falling oil prices should reduce consumer incentives to maintain demand-restraining practices, the overall effect of a price drop on demand for transportation fuel is less clear. Obviously, motorists are not going to trade in their current automobiles for pre-1973 gas guzzlers, and truckers are not going to dismantle air deflectors or fan clutches. Many conservation gains have been integrated into the structure of the transportation sector, and unless these improvements are perceived as reducing mobility or providing an inferior level of service (as measured by vehicle comfort, maintainability, performance, etc.), they are not likely to be abandoned in the face of a price drop. However, just as consumers responded to rising prices by conserving, they may be expected to react to falling prices by making incremental changes in their purchase decisions and travel patterns. In the aggregate and over time, these behavioral changes could produce a marked increase in petroleum demand.

The following discussion focuses on the long-term effects of lower petroleum prices on transportation activity and fuel use, as well as the implications for development of alternative fuels. Effects are identified by comparing the results of two scenarios, one with persistently low oil prices and moderately high economic activity, the other a prior "trend," or reference, forecast

based on the assumptions in the most recent National Energy Plan *(18)*. The trend scenario, referred to as ANL-85N (or simply 85N) in the following discussion, is described further elsewhere (unpublished information, M. Millar and A. Vyas, Argonne National Laboratory). The low-price scenario, based on DRI's spring 1986 low world oil price and optimistic economic growth forecasts, is described by DRI *(19, 20)* and referred to as ANL-86LOW (or simply 86L).

Both forecasts were generated with the Transportation Energy and Emissions Modeling System (TEEMS), a series of models developed and maintained by the Center for Transportation Research at Argonne National Laboratory (Argonne, Illinois). TEEMS is a disaggregate system of behavioral models that is sensitive to such economic and demographic factors as fuel price; household size, composition, and income; and sectoral economic activity, as well as to such vehicle and system attributes as relative modal cost, performance, and level of service. By using the economic and demographic features of the two input scenarios, TEEMS projects activity levels (i.e., vehicle-, ton-, or passenger-miles traveled) and energy consumption for all passenger and freight modes, as well as vehicle stocks and fleet average fuel economy for all highway modes. Because of the disaggregate nature of TEEMS, fuel price effects appear not only as changes in vehicle operating cost but also as changes in overall economic activity, household income, and other household attributes. Thus differences between the resulting forecasts reflect both direct and indirect price effects. [For a further discussion of the TEEMS methodology, see Vyas et al. *(21)*].

Features of the Two Scenarios

Figures 6 and 7 compare the major demographic and economic assumptions of both scenarios. Differences in labor force participation and household formation produce widening gaps (of more than 6 and 7 percent, respectively) in the numbers of employed individuals and households by 2010. Similarly, with a difference of 0.4 percent per year in economic growth, the gross national product (GNP) gap between the two scenarios widens to nearly 9 percent by 2010.

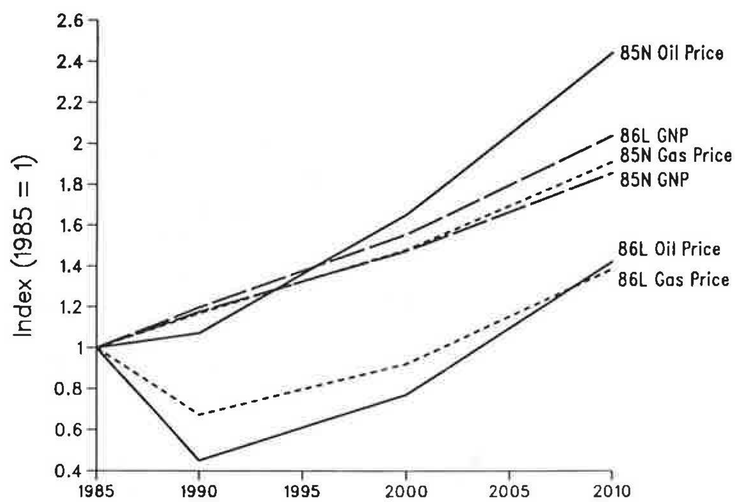

FIGURE 6 Key economic assumptions, ANL-85N and ANL-86L.

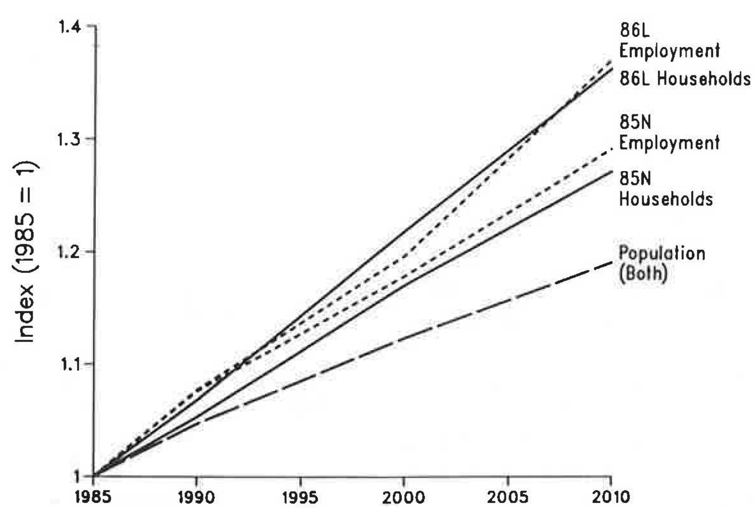

FIGURE 7 Key demographic assumptions, ANL-85N and ANL-86L.

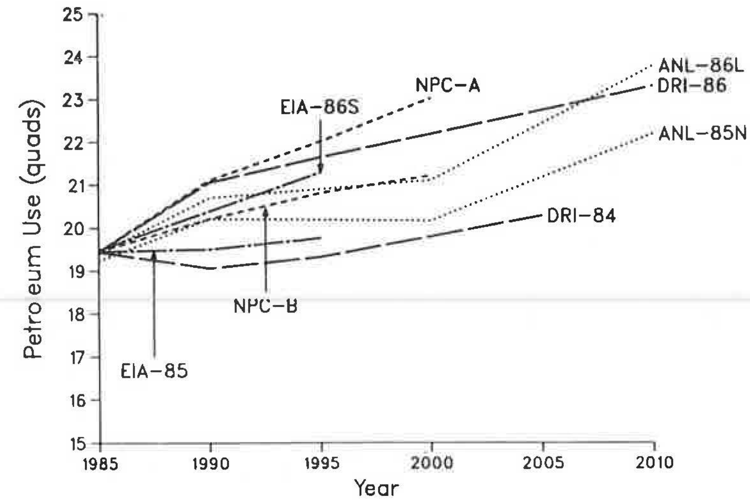

FIGURE 8 Forecasts of petroleum use in transportation. 1 quad = 10^{15} Btu [adapted from various sources (4–7)].

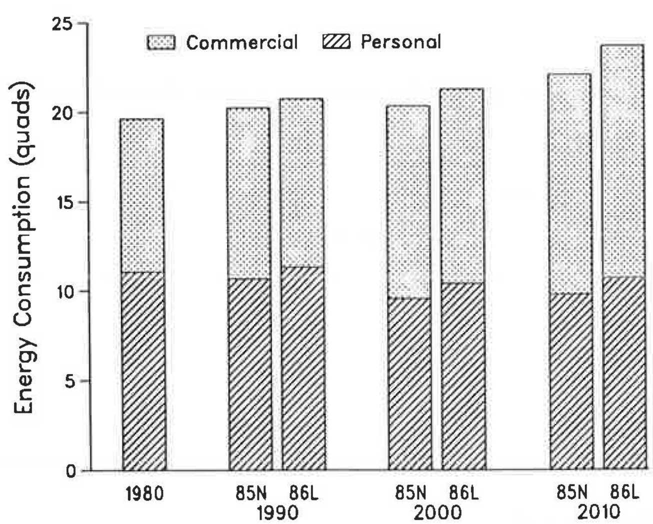

FIGURE 9 Energy consumption by commercial and personal vehicle uses, ANL-85N and ANL-86L. 1 quad = 10^{15} Btu.

Economic differences are even more pronounced at the sectoral level. Under the 86L scenario, growth varies from less than the overall GNP difference (i.e., less than 9.1 percent in 2010) in such sectors as primary metals and coal to more than twice the GNP difference in the food products, oil, natural gas, services, farm products, paper, and rubber and plastics sectors. As discussed later, these differences translate into relatively slower growth in modes transporting a high proportion of primary goods, despite higher overall growth in the low-price scenario.

Figure 6 also shows trends in world oil and retail gasoline prices. Under the 86L scenario, prices drop further and fail to regain their 1985 levels until beyond the year 2000. However, by that time, they are rising at faster annual rates than under the reference case (i.e., 6.3 percent versus 4.0 percent for crude oil and 4.1 percent versus 2.6 percent for gasoline).

Scenario Results

Tables 3 and 4 summarize energy use by mode under the two scenarios. Despite increased travel, consumption in both cases rises relatively slowly in the short term while currently available technologies continue to improve the efficiency of the vehicle stock. In the longer term, consumption accelerates in the absence of more radical technological improvements that are not considered in this effort. By 2010 the 86LOW forecast estimates 1.8 quads more energy use than the 85N forecast (1 quad = 1015 Btu). The largest differences occur in automobiles, light trucks, rail freight, and domestic water transportation.

As mentioned earlier, the scenarios are based on 1984 and 1986 DRI economic forecasts. Thus they show less overall variation than price effects would suggest because of important

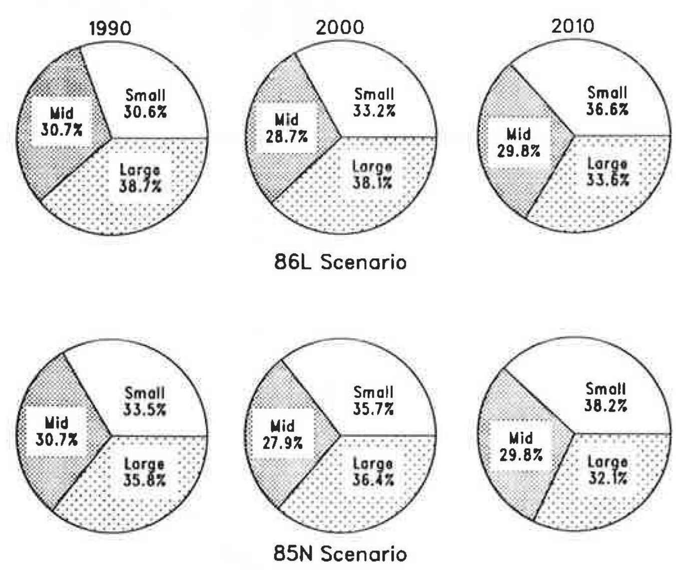

FIGURE 10 Automobile size shares, ANL-85N and ANL-86L.

TABLE 3 PROJECTIONS OF TRANSPORTATION ENERGY CONSUMPTION BY MODE AND SUBMODE, ANL-86L

Transportation Mode and Submode	Energy Consumption[a] (quads)				Change, 1980-2010 (%)	
	1980	1990	2000	2010	Total	Annual
Personal Vehicles	11.06	11.30	10.38	10.68	-3.4	-0.1
Automobiles	9.18	8.38	7.79	8.16	-11.1	-0.4
Light trucks[b]	1.88	2.93	2.59	2.52	34.0	1.0
Buses	0.14	0.18	0.21	0.26	85.7	2.1
School	0.05	0.05	0.06	0.07	40.0	1.0
Transit	0.06	0.09	0.11	0.13	96.9	2.3
Intercity	0.03	0.04	0.05	0.06[c]	115.2	2.6
Commercial Trucks	3.42	3.75	4.32	5.12	49.7	1.4
Light	1.02	1.12	1.21	1.42	39.2	1.1
Heavy	2.39	2.62	3.11	3.70	54.8	1.5
Rail	0.61	0.81	1.07	1.42	132.8	2.9
Freight	0.55	0.74	1.00	1.34	143.6	3.0
Passenger	0.07	0.06	0.07	0.08	14.3	0.4
Transit/commuter	0.04	0.05	0.06	0.07	51.2	1.4
Intercity	0.02	0.01	0.01	0.01[c]	-18.8	-0.7
Marine	1.78	1.69	2.13	2.72	52.8	1.4
Domestic freight	0.39	0.46	0.53	0.64	64.1	1.7
International freight[d]	1.22	1.00	1.30	1.71	40.2	1.1
Recreational[b]	0.18	0.24	0.30	0.38	94.4	2.2
Aviation	1.58	1.97	2.10	2.40	51.9	1.4
General aviation	0.18	0.25	0.47	0.40	122.2	2.7
Domestic passenger	1.22	1.47	1.31	1.58[c]	29.5	0.9
International passenger[e]	0.14	0.19	0.22	0.28	100.0	2.3
Domestic freight	0.04	0.07	0.09	0.13	225.0	2.7
Pipeline	0.84	0.83	0.81	0.78	-7.1	-0.2
Natural gas	0.68	0.65	0.62	0.58	-14.7	-0.5
Crude oil	0.09	0.10	0.11	0.12	33.3	1.0
Petroleum products	0.07	0.07	0.07	0.08	14.3	0.4
Coal slurry[f]	0.00	0.00	0.00	0.00	0	0
Miscellaneous Vehicles[b,g]	0.20	0.19	0.21	0.25	25.0	0.7
Total Energy[h]	19.61	20.72	21.23	23.62	20.4	0.6

[a]Modal values may not equal submode totals due to rounding; 1 quad = 10^{15} Btu.

[b]Includes minivans.

[c]Rough estimate derived by extrapolating 1980-2000 growth.

[d]U.S. sales of bunker fuels. Includes foreign-flag and some military consumption.

[e]Fuel purchases in U.S. by domestic carriers (assumes 50% is purchased overseas).

[f]Assumes no new construction of coal slurry pipelines (0.004 quad).

[g]Motorcycles, snowmobiles, and off-highway trucks.

[h]Excludes most military consumption, U.S. fuel purchases by foreign-flag air carriers, and all lubricants.

TABLE 4 PROJECTIONS OF TRANSPORTATION ENERGY CONSUMPTION BY MODE AND SUBMODE, ANL-85N

Transportation Mode and Submode	Energy Consumption[a] (quads)				Change, 1980-2010 (%)	
	1980	1990	2000	2010	Total	Annual
Personal Vehicles	11.06	10.06	9.54	9.75	-11.8	-0.4
Automobiles	9.18	8.03	7.20	7.49	-18.1	-0.7
Light trucks[b]	1.88	2.62	2.34	2.26	20.2	0.6
Buses	0.14	0.18	0.20	0.23	62.9	1.6
School	0.05	0.05	0.05	0.07	40.0	1.0
Transit	0.06	0.09	0.10	0.10	83.3	1.9
Intercity	0.03	0.04	0.05	0.06[c]	115.2	2.6
Commercial Trucks	3.42	3.71	4.08	4.58	33.8	1.0
Light	1.02	1.04	1.10	1.42	20.7	0.6
Heavy	2.39	2.67	2.99	3.35	39.9	1.1
Rail	0.61	0.83	1.11	1.45	140.6	3.0
Freight	0.55	0.77	1.04	1.34	150.4	3.1
Passenger	0.07	0.06	0.07	0.38	0	0
Transit/commuter	0.04	0.05	0.05	0.07	50.0	1.2
Intercity	0.02	0.01	0.01	0.01[c]	-18.8	-0.7
Marine	1.78	1.68	2.06	2.52	41.2	1.2
Domestic freight	0.39	0.43	0.49	0.55	42.3	1.2
International freight[d]	1.22	1.02	1.28	1.61	32.0	0.9
Recreational[b]	0.18	0.23	0.29	0.35	94.4	2.2
Aviation	1.58	1.88	1.89	2.31	46.1	0.5
General aviation	0.18	0.24	0.30	0.38	108.3	2.5
Domestic passenger	1.22	1.40	1.28	1.54[c]	26.6	0.8
International passenger[e]	0.14	0.18	0.22	0.28	97.9	2.3
Domestic freight	0.04	0.06	0.09	0.12	192.5	3.6
Pipeline	0.84	0.82	0.80	0.73	-13.9	-0.5
Natural gas	0.68	0.67	0.64	0.57	-16.2	-0.6
Crude oil	0.09	0.09	0.09	0.09	-4.4	0.2
Petroleum products	0.07	0.07	0.07	0.07	-7.1	0.2
Coal slurry[f]	0.00	0.00	0.00	0.00	0	0
Miscellaneous Vehicles[b,g]	0.20	0.19	0.21	0.25	25.0	0.7
Total Energy[h]	19.61	19.95	20.04	21.83	11.3	0.4

[a]Modal values may not equal submode totals due to rounding; 1 quad = 10^{15} Btu.

[b]Includes minivans.

[c]Rough estimate derived by extrapolating 1980-2000 growth.

[d]U.S. sales of bunker fuels. Includes foreign-flag and some military consumption.

[e]Fuel purchases in U.S. by domestic carriers (assumes 50% is purchased overseas).

[f]Assumes no new construction of coal slurry pipelines (0.004 quad).

[g]Motorcycles, snowmobiles, and off-highway trucks.

[h]Excludes most military consumption, U.S. fuel purchases by foreign-flag air carriers, and all lubricants.

TABLE 5 PRINCIPAL VARIABLES RESPONSIBLE FOR DIFFERENCES IN ENERGY USE BETWEEN THE TWO FORECASTS IN 2000 (PERCENT DIFFERENCE, 86L VERSUS 85N)

	Highway Modes				Nonhighway Modes						
Variable	Auto	Personal Light Truck	Commercial Light Truck	Heavy Truck	Rail Freight	Domestic Water	Intl. Water	Air Passenger[a]	Pipeline	Misc. Modes[b]	Total All Modes
Fuel Price	6.0	7.7	0.7	1.0	0.8	0.4	c	2.5	c	c	3.4
Economic Activity	d	d	10.1	3.2	-5.4	8.4	1.5	d	2.3	2.2	1.2
Household Growth	4.1	6.3	e	e	e	e	e	e	e	c	2.2
Household Demographics	-2.1	-2.9	e	e	e	e	e	e	e	0.6	-1.1
Coal Production[f]	e	e	e	-0.8	-4.4	-2.1	c	e	c	c	-0.4
Synergistic and Other	0.1	-0.2	0.1	0.8	1.8	2.1	0	0	0	0	-0.7
Total Difference (86L/85N)[g]	8.1	10.9	10.9	4.2	-7.2	8.8	1.5	2.5	2.3	2.7	4.6

[a]Domestic and international.

[b]Recreational boating, general aviation, air freight, bus, rail passenger, etc.

[c]Included in economic effect.

[d]Included in price effect.

[e]Not applicable; TEEMS module insensitive to parameter.

[f]Reduced output from the coal sector, all other sectors unchanged.

[g]Values may not sum to total shown due to rounding.

differences in their underlying economic assumptions. This may be seen in Table 5 in which consumption differences are allocated between the two scenarios (4.6 percent in the year 2000) to the influence of several independent variables. Fuel price is clearly the key factor (although household growth and demographic changes are also extremely important) in accounting for variations in automobile and personal light truck energy consumption, while economic activity is most important in explaining differences in commercial vehicle energy consumption.

The marked difference in the influence of economic activity on the forecast of energy use by light versus heavy trucks reflects both (a) the 86L scenario's substantially stronger growth of service sectors, which tend to rely on lighter vehicles; and (b) the forecasting methodology, which simulates the shipment decisions of goods-generating sectors by using modal cost and service attributes. Thus, while trucks compete with rail and water modes for goods shipments, they capture all service traffic. For nonhighway freight modes, differences in energy use also reflect sectoral variability in economic activity. For example, the combination of lower outputs of coal and primary metals and higher outputs of oil and agricultural goods tends to increase waterborne freight in the 86L forecast.

Figure 8 shows a comparison of transportation petroleum use under the 86L and 85N forecasts with that in other recent forecasts. The DRI-4 forecast has both the lowest petroleum use and, as shown in Table 2, the highest oil price. Conversely, the lower of the two NPC price forecasts (termed NPC-A in

TABLE 6 FLEET AVERAGE FUEL ECONOMY BY VEHICLE SIZE CLASS AND FUEL TYPE, ANL-86L

Vehicle Size Class and Fuel Type	On-Road Fuel Economy (mpg)				Improvement, 1980-2010 (%)
	1980[a]	1990	2000	2010	
Automobiles	15.2	21.0	25.3	27.1	79.1
Small	18.7	26.0	31.0	32.6	74.1
Medium	15.2	21.5	25.8	27.2	79.1
Large	13.1	17.8	21.4	22.7	73.3
Gasoline	15.1	20.9	25.2	26.9	78.3
Diesel	21.5	28.4	33.4	36.1	67.9
Trucks	9.8	13.3	14.1	14.7	50.0
Personal light[b]	13.0	18.2	20.7	22.5	73.5
Gasoline	13.9	19.2	21.7	23.6	83.0
Diesel	17.0	22.6	25.2	28.1	65.7
Commercial light (Classes 1-2)[c]	14.0	16.7	19.4	20.6	46.9
Gasoline	14.0	16.7	19.1	20.3	45.0
Diesel	17.0	17.9	21.0	22.2	30.6
Medium (Classes 3-5)	7.0	8.3	8.6	9.0	28.6
Gasoline	7.0	8.2	8.5	8.7	24.3
Diesel	7.3	8.8	9.1	9.4	28.8
Light-heavy (Class 6)	5.8	6.8	7.2	7.6	30.9
Gasoline	5.8	6.4	6.7	6.9	19.0
Diesel[d]	6.0	7.2	7.5	7.8	30.0
Heavy-heavy (Class 7-8)	4.9	5.7	6.0	6.5	33.3
Gasoline	4.4	4.9	5.2	5.2	18.2
Diesel[d]	4.9	5.7	6.1	6.5	32.7

[a]The low variation in historic gasoline vs. diesel truck fuel economy within size classes is attributed to relatively more demanding mission requirements for diesel vehicles. With increased penetration of diesels in vehicles with less-demanding missions, the average fuel economy of diesels should increase so that the gasoline vs. diesel variation will widen.

[b]Includes minivans.

[c]Size classes based on manufacturers' weight classes.

[d]Assumes electronic controls will offset only a portion of the fuel-economy penalty associated with EPA's proposed emission standards for new heavy-duty vehicles.

TABLE 7 FLEET AVERAGE FUEL ECONOMY BY VEHICLE SIZE CLASS AND FUEL TYPE, ANL-85N

Vehicle Size Class and Fuel Type	On-Road Fuel Economy (mpg)				Improvement, 1980–2010 (%)
	1980[a]	1990	2000	2010	
Automobiles	15.2	21.7	26.8	28.4	77.2
Small	18.7	26.7	32.8	34.1	75.2
Medium	15.2	21.6	26.7	27.8	75.5
Large	13.1	18.3	22.7	23.8	72.9
Gasoline	15.1	21.6	26.7	28.2	76.8
Diesel	21.5	29.0	35.1	37.6	63.3
Trucks	9.8	13.1	14.4	14.9	52.0
Personal light[b]	13.0	19.8	22.9	24.4	87.7
Gasoline	12.9	19.7	22.6	23.9	85.3
Diesel	17.0	25.4	30.5	31.7	86.5
Commercial light (Classes 1-2)[c]	14.0	17.8	20.6	22.0	57.1
Gasoline	14.0	17.7	20.4	21.6	54.3
Diesel	17.0	19.1	22.3	23.6	38.8
Medium (Classes 3-5)	7.0	8.3	8.9	9.3	32.9
Gasoline	7.0	8.2	8.5	8.7	24.3
Diesel	7.3	8.8	9.5	9.8	34.2
Light-heavy (Class 6)	5.8	6.8	7.6	8.0	37.9
Gasoline	5.8	6.4	6.7	6.9	19.0
Diesel[d]	6.0	7.2	7.8	8.1	35.0
Heavy-heavy (Class 7-8)	4.0	5.7	6.3	6.8	38.8
Gasoline	4.4	4.9	5.2	5.2	18.2
Diesel[d]	4.9	5.7	6.3	6.8	38.8

[a]The low variation in historic gasoline vs. diesel truck fuel economy within size classes is attributed to relatively more demanding mission requirements for diesel vehicles. With increased penetration of diesels in vehicles with less-demanding missions, the average fuel economy of diesels should increase so that the gasoline vs. diesel variation will widen.

[b]Includes minivans.

[c]Size classes based on manufacturers' weight classes.

[d]Assumes electronic controls will offset only a portion of the fuel-economy penalty associated with EPA's proposed emission standards for new heavy-duty vehicles.

Figure 8) has the highest petroleum use and the lowest oil price (see Table 2). In all cases, lower oil prices appear to result in some two additional quads of oil use by 2010.

Figure 9 shows a comparison of energy consumption by type of vehicle use under the two ANL scenarios. All automobiles and personal light trucks are considered personal vehicles; all other highway and nonhighway modes (e.g., other trucks, aircraft, ships, etc.) are considered commercial vehicles. For both purposes, energy use under the two scenarios differs by approximately 10 percent by 2010. Only a small portion of this difference is attributable to increased travel in response to lower fuel prices. Most occurs as a result of the strong relationship between fuel price and fuel economy (see Tables 6 and 7), mediated by several key intervenors. In the 86L scenario, reduced fuel economy arises from a combination of size shifts (see Figure 10), declines in diesel shares, and a slowing in the pace of technology improvement within individual size classes. All three of these results are produced by lower fuel prices and in turn produce lower fuel efficiency.

Price elasticities calculated from the TEEMS fuel economy forecasts are nonlinear. For the two scenarios described here, results translate into a fuel economy elasticity of 0.1 mpg for the entire automotive fleet in 1990, rising to 0.2 mpg in 2000. These compare with elasticities for new automobiles ranging from 0.1 in the short run to 0.7 mpg or higher in the long run, on the basis of results reported in the general literature *(22–24)*.

CONCLUSIONS

As would be expected, both consumers and businesses were delighted with the dramatic decline in petroleum prices during

1986. Individuals could look forward to an extended period of reduced travel costs, and businesses could anticipate that the costs of one production factor would be lower for perhaps several years.

As in most cases, however, trade-offs are involved. This is especially true with respect to the national policy issues associated with oil supply and demand. Lower world oil prices have the immediate effect of lessening the nation's import costs. Over time, however, lower prices spur consumption, reduce the demand for improved fuel efficiency, and diminish incentives for domestic oil exploration and development. Thus the volume of imported oil increases and the nation's import costs rise over time.

In the short run, increased oil imports do not negatively affect the national economy or dramatically increase the potential for oil supply disruptions. However, this assumption often precludes discussion of longer-run economic effects and vulnerability to supply interruptions. With domestic reserves already declining and lower oil prices increasing the consumption of energy, the United States can expect to be importing more oil by the late 1990s than it ever has. Thus the long-term consequences of low oil prices greatly increase oil import costs and vulnerability to supply interruptions and may, in fact, offset most of the benefits of the Strategic Petroleum Reserve and the fuel efficiency and conservation actions that have been implemented to date.

In such a future, the demand for improved fuel efficiency and fuel flexibility continues to decline. This is already becoming apparent in stable-to-declining new car fuel economy. While lower fuel prices increase economic activity, they also promote demographic and technological changes that elevate transportation energy demand long after fuel price effects have stabilized or even diminished. The increase in economic activity that occurs in the persistently low-price scenario results in a major increase in activity (and energy use) by the trucking sector, especially for commercial light trucks. Rail activity and energy use decline primarily because of a sharp drop in coal shipments that is caused by lower oil prices. Conversely, the increase in crude oil shipments largely benefits the maritime industry, increasing its year 2000 fuel demand by another 9 percent beyond that previously forecast. Changes in household travel demand also continue to be dominated by the influence of fuel prices, although growth in the number of households and a slight decline in average household income will have important effects on demand for transportation services.

Further, the decline in demand for improved fuel efficiency and flexibility is also likely to result in decreased R&D on alternative transportation fuels. Consequently, the transportation sector could be no closer to attaining a fuel-switching capability in the 1990s than it was in the 1970s.

Given the economic effects of oil supply disruptions in the past and the likelihood that oil prices will continue to be volatile in the future, there is some hope that energy policy objectives will shift from the recent desire to avoid government intervention to a need to learn from the past so that stability is introduced into the inevitable transition away from heavy dependence on foreign oil. In summation, persistently low oil prices, rather than being a cause for economic optimism, will accelerate the need for energy policies that reduce transportation petroleum demand while maintaining the expected high level of service in the transportation sector.

ACKNOWLEDGMENTS

This research was sponsored by the U.S. Department of Energy, Assistant Secretary for Conservation and Renewable Energy, under Contract W-31-109-Eng-38.

REFERENCES

1. *The Future of Oil Prices: The Perils of Prophecy.* Cambridge Energy Research Associates; Arthur Anderson & Co., Chicago, Ill., 1984.
2. *Energy Projections to the Year 2010.* Report DOE/PE-0029/2. Office of Policy, Planning and Analysis, U.S. Department of Energy, Oct. 1983.
3. A. S. Manne and L. Schrattenholzer. International Energy Workshop: A Summary of the 1983 Poll Responses. *The Energy Journal,* Vol. 5, No. 1, 1984, pp. 45–64.
4. *DRI Energy Review.* Vol. 8, No. 1, 1984.
5. *DRI Energy Review.* Vol. 10, No. 1, 1986.
6. *Factors Affecting U.S. Oil and Gas Outlook.* Report. National Petroleum Council, Washington, D.C., 1987.
7. *Impacts of Lower World Oil Prices on Energy Conservation.* Service Report. Energy Information Administration, U.S. Department of Energy, June 1986.
8. *World Energy Outlook Through 2000.* Conoco, Inc., Wilmington, Del., Sept. 1986.
9. *IGT World Reserves Survey.* Institute of Gas Technology, Chicago, Ill., 1986.
10. *Twentieth Century Petroleum Statistics 1982.* DeGolyer and MacNaughton, Dallas, Tex., Dec. 1982.
11. N. Gall. We are Living off our Capital. *Forbes,* Vol. 138, No. 6, 1986.
12. *Annual Energy Review 1985.* Report DOE/EIA-0385(85). Energy Information Administration, U.S. Department of Energy, May 1986.
13. *Two Energy Futures: National Choices Today for the 1990s.* American Petroleum Institute, July 1986.
14. Weak Prices, Lack of Drilling Dim Outlook for U.S. Reserves. *Oil and Gas Journal,* Vol. 84, No. 40, 1986.
15. *The Impact of Lower World Oil Prices and Alternative Energy Tax Proposals on the U.S. Economy.* Service Report. Energy Information Administration, U.S. Department of Energy, April 18, 1986.
16. C. Ebinger. Fool's Gold. Presented at Alternative Energy '86, Council on Synthetic Fuels and Synfuels, Captiva Island, Fla., June 1986.
17. L. King. *The Energy Crisis in Remission.* Senate Committee on Energy and National Resources, March 17, 1986.
18. *National Energy Policy Plan Projections to 2010.* Report DOE/PE-0029/3, Office of Policy, Planning and Analysis, U.S. Department of Energy, Dec. 1985.
19. *U.S. Long-Term Review.* Data Resources, Inc., Lexington, Mass., 1986.
20. *DRI Energy Review.* Vol. 10, No. 1, 1986.
21. A. Vyas, M. Millar, and P. Patterson. Transportation Energy Demand from 1980 to 2010: Structure and Results of the Transportation Energy and Emissions Modeling System. *Proc., 14th IASTED International Conference and Exhibition on Applied Simulation and Modeling,* Vancouver, British Columbia, Canada, 1986.
22. W. C. Wheaton. The Long-Run Structure of Transportation and Gasoline Demand. *The Bell Journal of Economics,* Vol. 13, No. 2, 1982, pp. 439–454.
23. *The Technology/Cost Segment Model.* Post-1985 Automotive Fuel Economy Analysis, Energy and Environmental Analysis, Arlington, Va., Nov. 1981.
24. R. W. Crandall et al. *Regulating the Automobile.* The Brookings Institution, Washington, D.C., 1986.

Publication of this paper sponsored by Committee on Energy Conservation and Transportation Demand.