DOCUMENT RESUME

ED 178 380 SO 012 030

AUTHOR Brown, Lester R.; And Others
TITLE The Future of the Automobile in an Oil-Short World. Worldwatch Paper 32.
INSTITUTION Worldwatch Inst., Washington, D.C.
SPONS AGENCY United Nations Environment Program, New York, N.Y.
PUB DATE Sep 79
NOTE 64p.
AVAILABLE FROM Worldwatch Institute, 1776 Massachusetts Avenue, N.W., Washington, D.C. 20036 ($2.00, quantity discounts available)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Conservation (Environment); *Depleted Resources; Developed Nations; Developing Nations; *Fuels; *Futures (of Society); Resource Allocations; *Social Change; Technological Advancement; Technology; *Transportation; Trend Analysis; World Problems

ABSTRACT

Possible future roles and designs of cars are examined in light of depletion of the earth's oil reserves. A major problem with regard to the rapidly changing world oil outlook is that cars will be competing with more essential claimants for scarce oil supplies including food production, industrial power, home heating, and running trucks and busses. Developing nations, which are particularly dependent upon the automobile, are likely to experience the most profound economic impact. Estimates of future oil supplies and prices maintain that $40-a-barrel oil is a distinct possibility in the near future and that the extraction of oil will soon begin to substantially exceed reserves and new discoveries combined. Leading candidates to replace petroleum as automobile fuel include alcohol, liquid fuels from coal, and oil from tar sands and oil shale. Although technology related to these fuels is improving, alternative fuels still cost more and do less than conventional automobile gasoline. Other means of solving automobile-related problems include improving automobile efficiency, reducing speed limits, producing smaller and less powerful cars, encouraging car pooling, and traveling by bus and train. (DB)

The Future of the Automobile in an Oil-Short World

Lester R. Brown
Christopher Flavin
Colin Norman

Worldwatch Paper 32
September 1979

This paper is based on the authors' forthcoming book, *Running on Empty: The Future of the Automobile in an Oil-Short World* (W. W. Norton, 1979). Research for the paper was supported by the United Nations Environment Program.

Sections of the paper may be reproduced in magazines and newspapers with acknowledgment to Worldwatch Institute. The views expressed are those of the authors and do not necessarily represent those of Worldwatch Institute and its directors, officers, or staff; or of the U.N. Environment Program.

Library of Congress Catalog Card Number 79-67316
ISBN 0-916468-31-3

Printed on recycled paper

Table of Contents

Each working day more than 100,000 automobiles roll off assembly lines around the world. Now the world's largest manufacturing industry, automaking has strongly influenced the economic and social evolution of modern industrial societies. The automobile achieved this eminence in an era when oil cost less than $2 a barrel and supplies seemed inexhaustible. Oil prices have now climbed past $20 a barrel, however, and supplies are increasingly uncertain. 5

This rapidly changing world oil outlook is beginning to affect both the design and the role of the automobile. It does not necessarily mean that the end of the automobile age is in sight. But it does suggest that things will never be quite the same. The implications extend well beyond the confines of the car industry, for certain assumptions about the future of the automobile underlie a vast range of daily public and private decisions.

Within the halls of government, decisions are being taken on the allocation of funds for the construction of highways and public transportation systems. Cities and suburbs are being designed on the assumption that use of the automobile will continue to expand. Third World governments, intent on building up their industrial capacity, are deciding whether to establish auto assembly plants and to encourage the development of automobile-centered transportation systems.

Within the private sector, automakers and associated manufacturers are formulating long-term production plans and marketing strategies. Managers of tourist facilities, builders of suburban shopping centers, and the owners of drive-in banks and theaters are relying on cars to bring them future customers. And designers of urban office buildings are deciding whether to incorporate subterranean parking garages.

For the individual, a decision to buy a car represents not only a major investment in the vehicle itself, but also a long-term commitment to buy the fuel to run it on. In the United States, it now costs about $20 to fill the tank of a standard American car; five years ago, it cost less than $10, and five years hence it is likely to be $50. In many European countries, it would already cost between $40 and $60 to fill a 20-

gallon tank. The salesperson selling an automobile can extoll its virtues, but neither the salesperson nor the manufacturer can guarantee the fuel to keep it running.

6 The automobile is now caught in a double bind. It will be affected not only by the leveling off of world oil production, but also by the fact that it will be competing with more essential claimants for scarce oil supplies. Producing food, powering factories, heating homes, and running trucks and buses will all require increased amounts of fuel in the years ahead. In this competition, the private passenger car will be progressively squeezed. It is in this rapidly changing energy setting that the future of the automobile must be reassessed.

World Automobile Trends

Both as an industry and as an important facet of economic and social life, the automobile plays a central role in most industrial nations. The use of cars continues to grow moderately in the United States and Western Europe, where they originated, but today most of the growth is in other parts of the world. Most obviously in Japan, and more recently in Eastern Europe, the Soviet Union, and many of the developing countries in Latin America and Asia, the rapid "automobilization" of society is still under way. In 1978, the global automobile population reached 302 million, a level of use that even Henry Ford would have had trouble envisioning.[1]

Automaking has since its beginning been revered as "the industry of industries," and the car's inventors compared with Julius Caesar and Genghis Khan in their influence on history. Its widespread use also brought forth a wave of doubts and outright criticism. By the twenties, philosopher Lewis Mumford and others were lamenting the dehumanization of the auto assembly lines, as well as the impact that increasing volumes of traffic were having on communities. More recently, Ralph Nader and Emma Rothschild have denounced the violence, waste, and pollution that accompany its spread.

Well-reasoned criticisms have never detracted noticeably from the automobile's allure, however, either for the travel-oriented consumer

"In 1978, the global automobile population reached 302 million, a level of use that even Henry Ford would have had trouble envisioning."

or for the profit-motivated corporation. The growth of the motor vehicle industry has been inexorable, slowing only slightly during worldwide recessions and often leading the way back to economic prosperity. Although experts at various times and in various countries have proclaimed a state of automotive "maturity"—when the ratio of cars to people is as high as it will ever be—no major country has yet experienced a real leveling off of its auto population. Any slackening of growth in some countries has always been quickly taken up in others. While the shape and size of cars have undeniably begun to pay homage to fuel questions, sheer numbers have not. From Spain to Brazil, the automobile continues to be a high priority for the consumer, its use expanding as quickly as personal incomes allow.

From the start, the development of the car has been an international phenomenon. The earliest breakthroughs on reliable engine-powered transportation were made in Europe, particularly in Germany, though it was Americans who first conceived of and then produced a car that was cheap enough to achieve mass acceptance. In 1916, with his revolutionary assembly line in full swing, Henry Ford produced a half million Model Ts. Under his leadership, the United States was producing 98 percent of the world's cars, a level of dominance from which other countries have only slowly recovered.[2]

In the following years, it was Americans who first came to depend heavily on the automobile. By 1929 there were 23 million cars on U.S. roads, or one for every five people—a degree of reliance that Japan and some West European countries are only now reaching. For most Americans, except the very poorest, both work and leisure were firmly caught up in the rising automotive tide. About 85 percent of the world's automobiles were being driven in the US and Canada, and virtually all of the rest in Britain, France, and Germany.[3]

The automotive revolution was briefly interrupted by the depression years of the thirties, and then more significantly slowed by World War II, as American and European factories quickly switched to the production of tanks and jeeps. However, as industrial countries began the process of postwar recovery, the automobile industry and a range of related businesses became leaders of the economic boom of the forties. Worldwide production jumped from barely one million cars per year at the close of the war to eight million in 1950. Annual

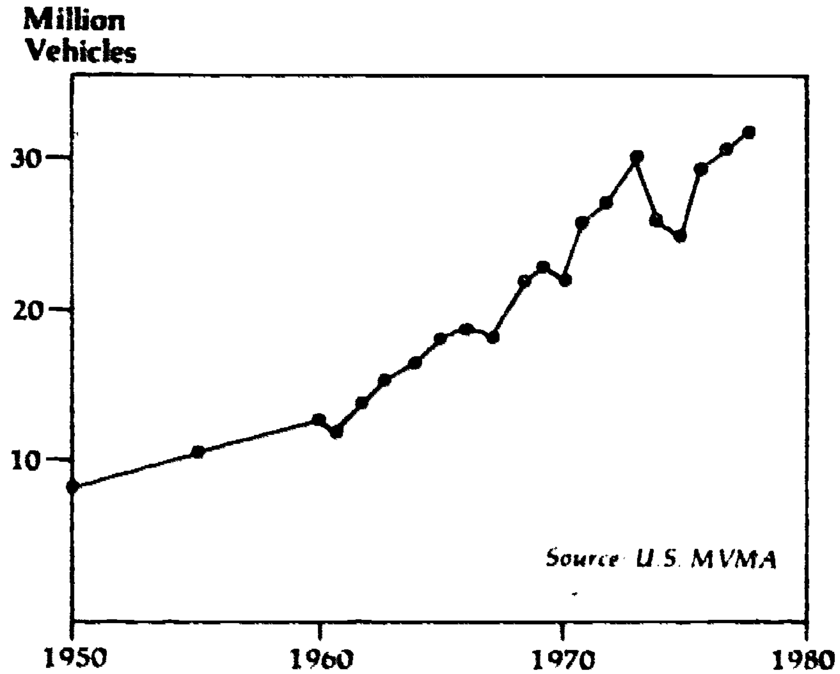

Figure 1: World Automobile Production, 1950-78

production since then has climbed more or less continuously, with the only major decline being a temporary one following the 1973 oil price hike. (See Figure 1.)

The increase in the number of cars on the road, on the other hand, has not slowed for even a moment. (See Figure 2.) At first the burst in auto usage followed the prewar pattern, for most growth occurred in those countries where an automotive industry and infrastructure already existed. Between 1950 and 1960, automobile ownership doubled in Britain, tripled in France, and quadrupled in West Germany, while American car use increased by 50 percent. Since 1960, growth in the United States has slowed significantly, compared with earlier levels, but it is still over 3 percent per year. The most advanced West European countries such as Britain, France, Germany, and Sweden have seen a similar easing in growth, though Italy, Spain, and other southern European countries are still adding cars at a near

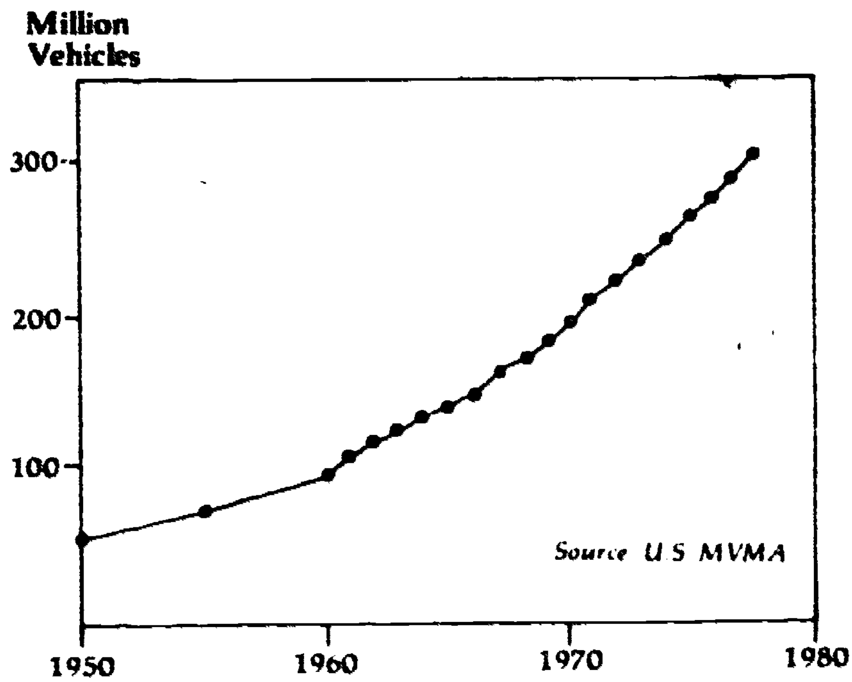

Figure 2: World Automobiles in Use, 1950-78

record pace. However, these moderating growth rates in North America and Europe have combined with explosive growth in other parts of the world to produce a tripling of the world car fleet since 1960—from 98 million to 302 million in 1978.[4]

During the sixties, the rapid growth in Japan's automobile fleet largely offset the slowdown in Europe and North America. From a mere one million in 1960, Japan's auto population has now reached 34 million—one car for every four people. Though growth rates have slowed from a phenomenal 12 percent annually in the mid-sixties, car ownership is still rising 5 to 6 percent each year. The Japanese are not yet as mobile as Europeans with comparable incomes, however, and the large number of licensed drivers without cars indicates a substantial amount of unfulfilled demand.[5]

Table 1: World Automobiles in Use, 1976

Region	Automobiles	Automobiles Per 1,000 Population	Share of World Total
	(million)	(number)	(percent)
United States	111	516	41
Canada	10	435	4
Western Europe	87	244	32
Oceania & S. Africa	9	163	3
Japan	18	161	7
Eastern Europe	9	61	3
Latin America	14	43	5
USSR	3	11	1
Africa (excl. S. Africa)	3	7	1
Asia (excl. Japan)	6	3	2
World Total	270	67	100

Source: U.S. Motor Vehicle Manufacturers Association, *World Motor Vehicle Data*

In recent years, many Third World and East European countries have been rapidly adopting the automobile. Countries such as Brazil and South Korea are putting cars on the road almost as rapidly as Japan once did. However, the geographic distribution of the automobile today remains as unequal as that of the world's oil reserves. Just over 40 percent of the world's cars are in the United States, close to one-third in Western Europe, 7 percent in Japan, and another 7 percent in Canada, Oceania, and South Africa. This means that 83 percent of the world's people own a mere 12 percent of its automobiles. (See Table 1.)

Americans also drive their cars much farther than other people do. In 1975, the average American drove over 15,000 kilometers (9,500 miles), compared with the average European's 6,300 kilometers and the mere 2,300 kilometers of the Japanese. (See Table 2.) To some extent this reflects a difference in geography, population concentration, and urban design. Most European and Japanese cities were planned before the advent of "urban sprawl." It also reflects rela-

Table 2: World Automobile Travel, 1975

Region	Distance Traveled	Distance Per Person	Car Share of Total Transport*
	(billion passenger kilometers)	(kilometers)	(percent)
United States	3,288	15,300	89
Canada	260	11,300	86
Western Europe	2,180	6,300	78
Oceania & S. Africa	230	4,900	70
Japan	253	,300	34
Eastern Europe	163	1,300	41
Latin America	357	1,100	68
USSR	112	400	11
Africa (excl. S. Africa)	34	100	33
Asia (excl. Japan)	145	100	10
World Total	7,022	1,700	63

*Bicycle and animal transport not included
Source: Robert U. Ayres, for Oak Ridge National Laboratory

tively lower personal incomes and more expensive cars and gasoline in Europe. In terms of sheer mobility, North Americans are clearly in a league of their own.[6]

Outside the industrial West, the disparities in automobile use are much greater. Eastern Europe and the Soviet Union have remarkably few cars; in fact, 89 percent of travel in the Soviet Union is by train or bus. East European governments have consciously limited vehicle use in order to devote industrial capacity to other purposes. The difference in priorities is clear: trucks and buses constitute more than half the vehicle population in the Soviet Union as opposed to 14 percent in Western Europe.[7]

The Third World as a whole depends even less on the automobile than Eastern Europe does, although national differences make the average figures nearly meaningless. Singapore and Argentina have close to 100 automobiles per thousand population, whereas Nigeria has just over three and India less than two per thousand. China has hardly entered the automotive age, with only 37,000 cars for almost one billion people. The major vehicle-owning Third World countries are Brazil, with seven million; Argentina and Mexico, with three million each; and Iran, with 1.5 million.[8]

In particular Third World cities, however, with wealthy urban populations, the concentration of vehicles is quite high. Sao Paulo and Mexico City have more cars than Philadelphia and San Diego do. In many developing countries, half the nation's cars are found in a single large city, and street systems are rarely extensive enough to accommodate them. Though there may be fewer cars than in European cities, congestion is usually much worse. From Bangkok to Lagos, "rush hour" now extends from dawn to dusk, making U.S. traffic problems appear calm and manageable by comparison.[9]

Yet the average person in a developing country never rides in an automobile. For the Third World, the above figures on passenger travel are misleading because they ignore bicycle and animal transport, which are much more important means of mobility for the average person. In India, 12 million bullock carts travel the country's roads, outnumbering the automobile fleet by more than ten to one.[10] And even the bullock cart is beyond the financial resources of many Third World people, so that walking assumes an importance that has long been forgotten in the industrial world.

The phenomenal increase in the production and use of cars over the last 50 years has had a profound economic impact. Today the economies of many countries rely heavily on the automobile—which generates both income and jobs in great quantities. The United States leads the way in this regard, having spent $180 billion—or over 10 percent of gross national product (GNP)—for automobile transportation in 1976. Parts manufacturers, car dealers, and service stations are among those who benefit most from these expenditures. But even these figures understate the economic role of the automobile, which has a large indirect impact. For the tourist industry, for example, the automobile plays a key role.[11]

No comparable figures are available for Western Europe and Japan, but it seems likely that some of these countries are approaching the

"It has been estimated that 30 million people around the world depend on automobiles or trucks for jobs."

U.S. level of economic dependence on the automobile. West Germans are now driving up to 60 percent as far as Americans do, and the British and French are not far behind. The Japanese economy is particularly dependent on the automobile markets of other countries —having exported half the vehicles produced in recent years. Even in Western Europe, the automobile accounts for 10 percent of the region's export trade. Many countries also rely on vehicle and gasoline taxes for substantial portions of government revenue; in France, for example, these taxes account for 16 percent of government funds.[12]

Automobiles have a major impact on personal finances as well. It has been estimated that 30 million people around the world depend on automobiles or trucks for jobs. Close to half of these are in the United States, where 22 percent of the work force is in the automotive sector. In Western Europe, five million jobs are dependent on the automobile. However, cars take as well as provide an individual's earnings. A recent study by the Hertz Corporation indicated that Americans spend 15 percent of their personal income on automobile transportation.[13]

The developing nations are not yet so economically reliant on the automobile, but many have been moving in that direction. World Bank data indicate that the transport sector accounts for between 3 and 10 percent of the GNP in most developing countries. Trucks are crucial in the development of a complex industrial economy because they have an ability to deliver a variety of goods to precise locations. And many Third World planners have found that encouraging automobile use with its accompanying tax contributions makes the building of adequate road networks more affordable. Large portions of public funds, ranging from 20 to 40 percent, are being devoted to the transport sector in these countries. Only in the wake of recent oil price increases have Third World leaders begun to question seriously journalist Nicholas Valéry's belief that "building up a nation's motor industry seems to offer the surest road to industrialization."[14]

Plans and trends for various countries around the world indicate that—in the absence of rapid policy changes in response to severe fuel shortages—automobile use will continue to increase rapidly in the near future. In few countries is a point of "saturation" in terms of consumer desire evident yet. Even in France, the United States, and

West Germany, total vehicle registrations, while growing more slowly, increased by over 20 percent during the recession-rocked 1972-77 period.[15]

In Eastern Europe and the Soviet Union, existing plans call for continuing growth in auto output. Soviet engineers have recently completed several large car and truck factories—setting the stage for further growth. Many of the automobiles are scheduled for export, however, and it appears that the Soviets will continue to give priority to the commercial vehicle over the private car. Many Third World countries hope to motorize their societies just as rapidly. South Korean planners, for instance, are considering a program that would boost the automobile population to 3.5 million by 1991, compared with 400,000 in 1979.[16]

Most middle-income Third World countries appear to be reaching a takeoff point where decisions must be made regarding the automobile. Many, like Korea, are in the middle of a vigorous debate over whether to build up this apparently glamorous indigenous industry. Others, at least for the present, are encouraging multinational corporations to build local assembly plants in order to fulfill the desires of a newly wealthy urban elite for cars. In Brazil, for example, European, American, and Japanese companies are all producing automobiles for this important market.[17]

Several recent studies have attempted to estimate the future size of the world car fleet. The conventional view in these projections, all undertaken before the recent reassessment of oil production and pricing policies, has been that growth will be more moderate than at any time since World War II. However, most experts have agreed that the rapid adoption of the automobile by East European and Third World countries will keep the world fleet expanding at a fairly rapid pace. Most recently, in 1979 the Organisation for Economic Cooperation and Development (OECD) projected that the world automobile population would almost double by the year 2000, rising at 3 percent per year during the eighties and nineties.[18]

However even this forecast, which is moderate by historical standards, does not take account of the changing fuel situation. During a period that is likely to see dwindling oil supplies and skyrocketing gasoline prices, economic and political pressures on the automobile will be

"The global automobile fleet now consumes about one-fifth of every barrel of oil produced in the world."

great in all countries. The ambitious plans that many nations have for the automobile may simply never be met.

Future Oil Supplies and Prices

In a world where automobiles run on oil, the relationship between the future of the automobile and future oil supplies and prices is an obvious one. Of the two principal automobile trends—annual production and the number of cars in use—the first is more immediately sensitive to changes in the oil situation.

Between 1950 and 1973, world oil output increased from just under 4 billion to over 20 billion barrels per year, a spectacular 7 percent annual rise. The annual production of cars, meanwhile, jumped from 8 million to 30 million—expanding at just under 6 percent per year. After the Organization of Petroleum Exporting Countries (OPEC) quadrupled the price of oil in late 1973, the growth in oil output fell sharply, averaging less than 2 percent per year between 1973 and 1978. Automobile production, influenced both by higher oil prices and by the associated economic slowdown, quickly followed a similar path and fell to less than 1 percent per year during the same period.

While annual automobile production has sometimes declined in response to short-term changes in the economic or energy outlook, the overall size of the automobile fleet has not. Since the end of World War II, its growth has been one of the most predictable of all international economic trends. Annual growth in the fleet—that is, the excess of new cars that are produced over older cars that are retired—has averaged some 15 million in recent years.

The global automobile fleet now consumes about one-fifth of every barrel of oil produced in the world. The share is highest in the United States, where cars account for almost one-third of total oil consumption. Together with vans and light pickup trucks—which often substitute for cars in everyday use—the American automobile burns more than six million barrels of gasoline per day. In Western Europe, where the automobile is not quite so predominant, it consumes about one-sixth of total oil supplies.[19]

The fivefold increase in world oil output between 1950 and 1973 was a remarkable production feat, one that future historians may marvel at. Lasting less than a generation, this period of spectacular growth ended abruptly with the OPEC price hike, which ushered in a new era in petroleum production and pricing policy. Similarly, it is now becoming clear that the Iranian revolution of early 1979 has set the stage for another reassessment of production and pricing policies in other oil-exporting countries. Governments of oil-exporting countries are actively considering the social impact of massive investments of petrodollars, the advantages of keeping oil in the ground during an era of accelerating inflation, and the foolishness of depleting remaining reserves too rapidly.

The Iranian experience illustrates some of the problems a sudden influx of capital can cause when programs to distribute the wealth equitably are not established. Iran's export earnings climbed from $4.8 billion in 1972 to some $22 billion in 1974. This windfall of wealth became concentrated in a few hands, which widened the gap between rich and poor and put an intolerable strain on the country's social fabric. When asked about the fall of the Shah's government, a deputy minister of oil from an Arab country who had been at the December 1978 OPEC conference said, "The one thought that keeps coming back is that it could have happened to any of us."[20]

Official thinking in Mexico already reflects a concern about the social impact of petrodollars. The United States and other oil importers have assumed that Mexico would want to join the ranks of the major petroleum exporters as quickly as possible. Yet a recent report from Mexico City indicates the government is already struggling to prepare enough projects for the expected influx of $5 billion in 1980. Officials of PEMEX, the state oil monopoly, have recently talked of a production plateau by late 1980 of 2.25 million barrels a day, of which about 40 percent would be for export. Many Mexicans now seem to agree with President López Portillo that "output should be kept down to levels commensurate with the country's ability to absorb the resulting massive revenues."[21]

The growing economic strength and independence of the oil-exporting countries is also influencing oil production and export levels. This independence is dramatically evident in Iran. The new leaders seem to be content producing not more than four million barrels a day, well below the pre-revolutionary daily level of some six million barrels. With 700,000 barrels to be set aside for domestic needs, the exportable oil supply is little more than half the earlier level. This recent policy was outlined by the new director of the Iranian Oil Company, Hassan Nazih, who explained to reporters that "our production policy will be dictated only by Iran's national interest."[22]

In the normal operation of any commodity market, rising prices simultaneously discourage consumption and encourage production. In the case of oil, however, a rising price can discourage production in some key oil-exporting countries where limited capital needs can be satisfied with a lower volume of exports at a higher price. Indeed, some OPEC members, such as Libya and Kuwait, responded to the fourfold 1973 price increase by sharply reducing their oil exports immediately thereafter.[23] Similar responses by other members of OPEC can be expected in the years ahead.

The inflation that has rocked every economy during the seventies is likely to discourage oil production in the short term. Uncertainty about the future value of money, particularly of the dollar, has convinced several oil-producing nations to keep as much of their wealth as possible underground. With $40-a-barrel oil a distinct possibility in the near future, the advantages of conservative production policies are becoming clearer to petroleum producers.

Important though the above influences on oil production are, they are probably dwarfed by the recent emergence of a "depletion psychology." As the extraction of oil begins to exceed substantially the additions to proven reserves through new discoveries, countries will be forced to reckon with the day when the wells go dry. The fear of using up the last of an irreplaceable resource is a subtle influence, not easily measured. But just as the changing market psychology led to dramatic oil price increases during the seventies, so the fear of depletion could severely restrict oil production during the eighties and beyond.

A conservationist strain is already evident in the production policies of several leading oil exporters. Bahrain, Iran, Kuwait, Libya, and Saudi Arabia now limit output to levels well below their potential. The influence of this depletion fear will be first evident in the Middle East, since "its reserves are being depleted at faster rates than the world average," as OPEC Deputy Secretary-General Fadhil al-Chalabi points out. In his farewell address as U.S. Secretary of

Energy, James Schlesinger reported that Middle East oil production was unlikely to expand more than 1 percent beyond the current level —and that it could just as likely fall below that level.[24]

For the principal oil exporters, the exhaustion of oil reserves means not merely the loss of an energy source, as it does for other countries, but the loss of economic sustenance as well. Kuwait's Oil Minister, Sheik Ali Khalifa al-Sabah, justifies his country's production ceiling by pointing out that "we know that it takes perhaps even a century to develop an economy. We have been producing oil for 35 years, and we are not developed yet. We'd like to see our oil last beyond 100 years."[25]

The long-term impact on world oil production of the Iranian revolution and the reassessment of oil production and price policies that it triggered is likely to be profound. The 1973 OPEC price rise slowed the growth in world oil production from 7 percent per year to 2 percent. The reassessment of oil policies that began in 1979 will almost certainly lower the rate of growth still further.

Projections based largely on the physical constraints on production—the reserve-to-production ratio, in particular—indicate that production is likely to increase somewhat further before peaking around 1990. A 1979 study by the International Energy Agency concludes "that world oil production is likely to level off sometime between 1985 and 1995." An early 1979 paper by David H. Root and Emil D. Attanasi of the U.S. Geological Survey reaches essentially the same conclusion: "Extrapolation of historical trends in exploitation and production, together with an estimate of the stock of oil in known fields, and the assumption that the crude oil reserve-to-production ratio never drops below 10, places the date of peak world production before the end of 1993."[26]

Although many earlier projections of world oil production show at least some modest further growth before peaking, even this is becoming doubtful. Most existing projections show oil production in the Soviet Union, the world's leading oil producer, continuing to rise for many years. Yet a recent report of oil production difficulties in the USSR indicates that it may already be turning downward. In a July 1979 speech, Robert O. Anderson, Chairman of the Board of the Atlantic Richfield Company, concluded that "world oil output is at

"Both the role and the design of the automobile in the future will be shaped by the price of gasoline."

or near its peak. This year or next could represent the highest level to be achieved." In August 1979, departing U.S. Secretary of Energy Schlesinger expressed doubts that world oil output would ever rise much beyond current levels.[27]

The prospects for increased production vary widely from country to country. Romania, the United States, and Venezuela have already used up much of their indigenous oil reserves. Once major oil exporters, both Romania and the United States are now importing roughly half their current supplies. Others, such as China, Mexico, and the United Kingdom, are still at the early stages of developing their national oil reserves.

In the United States—the country with the world's largest automobile fleet—oil production has been declining since 1970. Keeping American cars on the road now depends on vast imports of petroleum. While the countries of Western Europe have essentially frozen their oil imports at the 1973 level, the United States has raised its oil imports by fully one-third.[28]

Both the role and the design of the automobile in the future will be shaped by the price of gasoline, which in turn is tied to oil prices and gasoline taxes. Following the large OPEC price hike in late 1973, oil prices hovered in the range of $10–$13 per barrel through 1978. In early 1979, the cessation of oil exports from Iran for several weeks led to an exceedingly tight world supply situation. The stage was set for another major hike in the official OPEC price—in June 1979 the price was raised to $18–$23.50 per barrel overnight, the exact price depending on grade and geographic proximity to markets.[29]

On the "spot" market in Rotterdam, where small amounts of oil are sold to meet short-term needs not covered under contract, some cargoes have changed hands at $40 or more per barrel. A U.S. Department of Energy study about the impact of rising oil prices on the country's economy uses a $32-per-barrel price in one of its scenarios. And in August 1979, U.S. Secretary of Energy Schlesinger stated that $40-a-barrel oil was inevitable.[30]

In several countries—Bulgaria, East Germany, Greece, and Turkey—gasoline prices have recently passed $3 a gallon. (See Table 3.) Czechoslovakia, India, Japan, South Africa, and Yugoslavia are rapidly approaching the same level. France may become the first major Western industrial country to pass the $3 mark. Filling the tank of a standard-sized American car would cost $58 in France. Where gasoline prices are highest, they are either set by governments or they include a high tax. The tax exceeds $1 a gallon in several West European countries, including France ($1.10), Italy ($1.54), the Netherlands ($1.12), and West Germany ($1.02). In these countries, the tax alone exceeds the retail price of gasoline in the United States.[31]

Table 3: Price of Regular Gasoline in Selected Countries, August 1979

Country	Price
	(dollars/gallon)
Brazil	1.84
Bulgaria	4.25
Czechoslovakia	2.65
East Germany	3.38
France	2.90
Greece	3.24
India	2.50
Italy	2.23
Japan	2.49
South Africa	2.44
Turkey	3.05
USSR	1.20
United States	.92
West Germany	1.95
Yugoslavia	2.70

Source: Various articles in current periodicals.

Along with price, the supply of gasoline has recently posed a problem for motorists. Long waiting lines at service stations in a number of countries, particularly in the United States, dominated the news in the spring and early summer of 1979. This uncertainty about gasoline supply, combined with the seemingly endless announcements of OPEC price increases, depressed new car sales in the first eight months of 1979.

The seventies have seen a fundamental transformation in the global oil outlook. By the end of the decade, for the first time since the oil age began, the world's annual use of oil began to exceed the discovery of new reserves. As a result, proven reserves of oil are now shrinking with each passing year. As a special analysis in *Business Week* puts it, "The beginning of the end of the oil age is now in sight."[32]

Alternative Fuels

Although it has always been clear that the world's oil reserves would not last forever, little attention has been paid to the need to develop alternative liquid fuels. With a downturn in world oil production only a few years away, however, governments and corporations are belatedly turning to the development of petroleum substitutes.

Alcohol, liquid fuels from coal, and oil from tar sands or oil shale are the leading candidates to replace petroleum directly as an automotive fuel. While the technology to produce each of these products is relatively well known, they all face serious economic, environmental, or social problems that are likely to place major constraints on their large-scale use. An alternative approach—the development of electric vehicles that do not require liquid fuels at all—is also being vigorously pursued. But severe technological obstacles must be overcome before electricity can challenge petroleum as a way to run automobiles.

The substitute liquid fuel whose development is progressing most rapidly is ethyl alcohol, or ethanol. The technology for producing ethanol is relatively straightforward, for it differs little in principle from the centuries-old practice of distilling liquor from fermented grains and other plant materials. Ethanol can be produced from fermented sugar cane, cassava, sweet sorghum, corn, agricultural wastes, or municipal garbage.

The chief attraction of ethanol is that it can serve as a petroleum supplement simply by being mixed with gasoline, which produces a mixture popularly called gasohol. A blend that contains up to 20 percent ethanol provides a high-octane fuel that can be used directly in a conventional automobile engine. Although some engine modifications are required to burn pure alcohol, the conversion costs are relatively modest.

Leadership in alcohol production is coming from Brazil, a country that is heavily dependent on imported oil. Stung by the 1973 oil price increases, the government launched an ambitious program in 1975 to convert part of its large sugar crop into alcohol fuel. The original goal was to become self-sufficient by the end of the century; by 1979, alcohol production met 14 percent of Brazil's automotive fuel needs. Flushed with the early success of the program, and hit again by oil price rises in 1979, the Brazilian Government announced in mid-1979 that an additional $5 billion would be invested in new distilleries by 1985. In addition, 1.2 million new cars built between 1979 and 1985 will be designed to run on pure alcohol, and some 475,000 older cars will be converted. The government is also experimenting with the use of manioc, a root crop that thrives on poor soil, as a feedstock for its alcohol distilleries.[33]

The only other country producing significant quantities of alcohol to run cars is the United States. While the leadership in Brazil is coming from the government, in the United States it is largely the result of private initiative. The liquor industry, for example, is reactivating some old distilleries, and production of alcohol for automotive fuel in 1979 is expected to be approximately 100 million gallons—less than 0.1 percent of total automotive fuel consumption. Corn is the chief source of ethyl alcohol in the United States at present.[34]

A Department of Energy review of the potential for alcohol fuels in the United States, published in mid-1979, suggests that if all the land idled under farm programs were used to grow energy crops, and if large quantities of organic wastes such as cheese whey, citrus waste, and municipal garbage were used to make alcohol, the United States could produce 4.8 billion gallons of ethanol per year.[35] At just under 5 percent of current gasoline consumption, that amount would be a welcome addition to automotive fuel supplies, but it would certainly not provide salvation.

"Large-scale diversion of crops to distilleries will raise serious concerns about competition between food for people and fuel for automobiles."

The economics of large-scale alcohol production are somewhat gloomy. At early 1979 oil prices, ethanol in the United States cost roughly twice as much as gasoline, and it was retailing for about \$1.50 per gallon.[36] But as oil prices rise and as alcohol production begins to benefit from economies of scale, the cost difference should decrease.

Both Brazil and the United States are using tax policies to make alcohol and gasohol competitive with gasoline. In June 1979, alcohol was selling in Brazil for \$1.04 per gallon, for example, compared with \$1.52 for gasoline. In the United States, the federal government has exempted gasohol from the federal sales tax of 4¢ per gallon, and some states, such as Nebraska and Iowa, have also exempted it from state gasoline taxes. This provides a major subsidy for gasohol. As of mid-1979, gasohol containing 10 percent alcohol was being marketed in 28 states; in Iowa, it accounted for 2.5 percent of total gasoline sales in March 1979.[37]

The ultimate potential for ethanol as an automotive fuel is likely to rest on the availability of raw materials. In particular, large-scale diversion of crops to distilleries will raise serious concerns about competition between food for people and fuel for automobiles. Brazil is fortunate in having a large sugar surplus that can readily be converted into alcohol as well as considerable areas of land that could be used to grow energy crops. Few other countries have that luxury. The United States does have a substantial grain surplus that could be converted into alcohol, but diversion of a significant part of the surplus could result in less food being available for export in lean years. In effect, the purchasing power of American motorists could override the basic food needs of people in the developing world. Such questions need careful thought before rushing headlong into the large-scale use of ethanol to run cars.

A second alcohol, methanol, has a promising potential in the long term. Produced from wood or woody products, its use would not compete so directly for food resources and it could be produced from waste materials such as wood chips and other sawmill products. Methanol production technologies are not as advanced as those for ethanol, however, and methanol suffers from one serious drawback: it corrodes some of the metals used in automobile engines. Canada, richly endowed with forests, is beginning to examine seriously the possibility of large-scale methanol production, and Brazil has also recently begun to consider producing it.[38]

The possibility of producing so-called synthetic fuels from coal, oil shale, and tar sands has recently received much attention, particularly in the United States. In mid-1979, President Carter came up with a program to produce 500,000 barrels of synthetic fuels a day by 1985, and two million barrels by 1990. He proposed investing some $88 billion from the windfall profits tax (which will be levied on the oil companies if and when the price of oil is decontrolled) in synthetic fuels plants, and the U.S. Congress moved quickly to consider the proposal. The government's program is a direct response to the oil shortages and price rises of 1979, and it met with initial enthusiasm from an exasperated public. As Senator Dale Bumpers of Arkansas put it, "The American people are in the mood to do something, even if it is wrong."[39]

A process for producing liquid fuels from coal was developed by Germany before World War II. By the end of the war, the country was producing nearly 100,000 barrels a day, using the fuel to power its entire air force and its panzer divisions. Once the war was over, however, German industry went back to refining imported oil, a much cheaper alternative at the time. Today, only one country—South Africa—is operating a commercial coal liquefaction plant.[40]

Highly vulnerable to oil embargoes, South Africa opened a plant for converting coal into liquid fuel in 1959. The facility produces an estimated 20,000 barrels of liquid fuel per day, close to 10 percent of the nation's oil needs. A much larger plant was commissioned in 1974 and, following the Iranian Government's embargo of oil to South Africa, a major expansion of the plant was announced in March 1979. Scheduled to open in 1982, the $6.7 billion facility will produce sufficient synthetic fuel to meet about half South Africa's projected oil needs.[41]

While no other country has a commercial plant in operation, a demonstration facility will soon be built in the United States. Designed to convert 6,000 tons of coal per day into 20,000 barrels of oil, the plant is scheduled for completion by early 1985. It will be built in West Virginia with funds from the U.S. and West German Governments, a consortium of Japanese firms, and the Gulf Oil

Corporation, which will design and operate the plant. Several other pilot plants, capable of producing only a few hundred barrels of oil a day, are being built in the United States by private industry to test different technologies for producing liquid fuels from coal.[42]

One of the attractions of coal as a source of synthetic oil is its relative abundance. The same is true of oil shale and tar sands. Deposits of these fuel sources in Canada, Colombia, the United States, and Venezuela contain far more oil than is left in the oil fields of the Middle East. The great difficulty is devising an economical and environmentally acceptable process for extracting the oil.

Tar sands are a mixture of sand, water, and a thick hydrocarbon called bitumen. They look like black, sticky dirt. Production of synthetic oil from tar sands involves mining the sands with huge draglines, treating them with hot water and steam to extract bitumen, and chemically treating the bitumen to produce a synthetic oil that can be processed in a conventional refinery. Oil from tar sands resembles natural petroleum in physical appearance, but not in price: a commercial tar sands plant in Canada has been producing synthetic oil at between $30 and $45 a barrel.[43]

Commercial production of oil from tar sands is currently limited to Canada. A consortium consisting of oil companies and the Canadian Government has invested some $1.9 billion in a facility in Alberta Province. Plagued with engineering and environmental problems, the plant has been producing about 50,000 barrels of synthetic crude oil per day, although it is designed to produce twice that amount. A second, smaller venture in Alberta is run by a subsidiary of the U.S. Sun Oil Company, but it has been operating at a loss ever since it opened a decade ago. Experience gained in these early Canadian facilities may eventually result in a more economical process that will provide oil at a price competitive with the far higher world oil prices of the future.[44]

The extraction of oil from shale deposits is even more difficult and costly than the production of oil from tar sands. The world's richest oil shale deposits lie in an area around the junction of Colorado, Utah, and Wyoming in the United States, where oil is tightly locked into rock formations just beneath the surface. Extracting the oil requires mining the rock, crushing it, heating it in a furnace, condensing the oil, and partially refining it. An alternative process developed by Occidental Petroleum, which involves heating crushed shale rock underground, requires the mining of less rock, but it has yet to be tested on a large scale.

26 Oil shale development attracted a flurry of interest from several companies following the 1973 oil price rises, but that interest waned rapidly in the face of the enormous technical difficulties and the huge capital costs involved. After building small pilot plants, many firms have withdrawn from oil shale development, and no commercial ventures have been attempted. A few larger plants are on the drawing board, but the companies concerned are mostly awaiting government subsidies before pushing ahead with construction.[45]

The costs of producing synthetic oil from coal and shale are highly uncertain. The estimated production cost has remained above the price of crude oil during the past few years. In 1972, for example, the National Petroleum Council estimated that oil could be produced from coal for between $7.75 and $8.25 a barrel, while oil from shale would cost $8.29 a barrel. If these estimates were realistic and had held steady, investments in synthetic fuels plants would have been extremely attractive as the world oil price rose. Instead, now that oil is about $20 per barrel, the expected cost of producing liquid fuel from coal has climbed to about $38 per barrel, while that of oil from shale is between $25 and $35. It is not surprising that industrial investment in synthetic fuels facilities has been modest.[46]

While the production costs for synthetic fuels may be uncertain, it is clear that the initial capital costs will be enormous. President Carter's proposal to sink $88 billion into synthetic fuels plants is only part of the estimated cost. Facilities capable of producing five million barrels of oil a day—about one-fourth of the total U.S. oil consumption—require investments of up to $300 billion, according to some authorities. Such massive capital outlays would divert investments from other areas, including energy conservation programs that could save far more oil than the synthetics program is likely to produce.[47]

Although the capital constraints are daunting enough, other problems are likely to pose an even greater obstacle to synthetic fuels production. Every barrel of shale oil requires the mining and processing of about one-and-one-half tons of rock, which means that a one-million-barrel-a-day shale oil industry would dig up almost as much material as the entire U.S. coal industry now mines. The demand for water is also a serious problem. Between two and five barrels of water are required to produce each barrel of shale oil, and up to 13 barrels of water are needed to produce each barrel of liquid fuel from coal. The synthetic fuels industry would be located in a part of the United States where water is already scarce and where demand for water from both agriculture and urban development is growing rapidly.[48]

A massive shift to synthetic fuels would also release large amounts of carbon dioxide, which in turn could lead to a warming of the earth's atmosphere. A panel of scientists reported to the U.S. Council on Environmental Quality in July 1979 that more carbon dioxide is released from the production and combustion of synthetic fuels than from the direct burning of coal, and warned that "if we wait to prove that the climate is warming before we take steps to alleviate the carbon dioxide buildup, the effects will be well under way and still more difficult to control."[49]

With these rather dismal prospects of finding acceptable replacements for automotive fuels in the near future, the alternative of developing engines that do not require liquid fuels clearly merits considerable attention. Ever since the 1973 oil embargo focused attention on the automobile's thirst for oil, electric power has been widely touted as the fuel of the future. Expanding the use of electric vehicles would begin to wean cars from their near-total dependence on oil—provided the electricity does not come from oil-fired power plants—and it would help reduce pollution in congested cities.

In spite of the enthusiasm for electric vehicles, they are not yet close to challenging automobiles powered by the internal-combustion engine. Their chief drawback is the relatively poor performance of the lead-acid batteries that are available today. Battery technology has changed little in the last hundred years: the batteries that now propel golf carts and forklift trucks are not radically different from those that powered automobiles at the turn of the century, when about 40 percent of the cars made in the United States ran on electricity. Electric vehicles were eclipsed by gasoline-powered automobiles shortly before World War I, and their sales have never recovered. In fact, sales today are about the same as they were three-quarters of a century ago.[50]

The fundamental problem with electric vehicles is that they cost more but do less than conventional automobiles. They have a limited range—typically less than 50 miles—before the batteries must be recharged. They are extremely sluggish, both in terms of acceleration and top speed. There are safety problems related to the fact that potentially explosive amounts of hydrogen can be given off during recharging. And their batteries must be replaced every two or three years at a cost of more than $500. There are some promising developments, however.

The U.S. Department of Energy has begun a major effort, costing $160 million over five years, to improve electric vehicle technology. In mid-1979, it unveiled a prototype vehicle, built under contract by General Electric and Chrysler, that incorporates several advanced features. Powered by 18 six-volt lead-acid batteries, it can manage about 70 miles of city driving fully loaded before it needs recharging, and the batteries can be recharged up to 500 times before they wear out. While its acceleration is still slow compared with gasoline-driven vehicles, it has a top speed of about 60 miles per hour. Its performance, in short, is adequate for most urban trips. A test vehicle with similar characteristics was produced in Britain in 1978 by the Lucas Corporation.[51]

The Department of Energy's prototype electric vehicle is obviously not the last word in this technology, but there are doubts about how much more lead-acid batteries can be improved. A few weeks before the prototype was completed, for example, the General Accounting Office castigated the Department of Energy for relying too heavily on conventional battery technology, and recommended that more funds be put into research and development of a lighter, more durable, more powerful alternative. So far, however, alternative systems have proved elusive. Although several possibilities are on the drawing board—a nickel-zinc oxide battery, in particular, shows promise—their cost, reliability, and ability to withstand repeated recharging need much improvement.[52]

It will clearly be many years before a radically improved electric vehicle can be put into production. In the meantime, however, there is a potential market for electric delivery vehicles using existing technology. About 40,000 electric vehicles are already on the road in Britain, taking milk, eggs, and other goods around local communities,

"About 40,000 electric vehicles are already on the road in Britain, taking milk, eggs, and other goods around local communities."

and the U.S. Postal Service is now buying a small fleet for test purposes. The U.S. Department of Energy estimates that there could be about eight million electric vehicles on the road in the United States by the year 2000, which would result in a savings of about 200,000 barrels of oil a day.[53]

The need for alternative fuels increases with every OPEC price rise and every new driver who wants to buy a car. At this point, one thing is clear: there are neither cheap ready substitutes for petroleum nor reliable vehicles that do not require liquid fuels. In the absence of such technological fixes, efforts to conserve petroleum will assume increasing importance.

More Efficient Automobiles

With oil shortages looming and the prospects for alternative fuels uncertain, the need to make cars more efficient is both obvious and urgent. Indeed, the future of the automobile in an oil-short world may largely rest on the success of efforts to wring more miles from each gallon of automotive fuel.

Opportunities abound for improving the efficiency of automobiles, for energy consumption has long taken a back seat in vehicle design. Three-quarters of a century of automotive engineering has produced vehicles that are fast, comfortable, and quiet. But they are by no means efficient. Cars rolling off Detroit's production lines in the early seventies consumed more energy per mile than did their predecessors in the thirties, and the 1973 oil embargo came just as the American automobile industry was making its most inefficient range of cars since World War II. Even in Europe, where automobiles are more frugal with gasoline than their American counterparts are, there is substantial room for improvement.

Over the past few decades, automobiles have grown heavier and more powerful, and they have become laden with such energy-consuming devices as automatic transmissions and air conditioning. Three-speed automatic transmissions introduced in the thirties swiftly captured the American market, for example, and by the late sixties large V-eight engines were installed in almost 90 percent of the cars sold in the United States.[54] Lack of attention to fuel consumption was understandable when the price of oil was declining in relation to the price of most other goods. But that era has clearly ended.

Consumers are now demanding more efficient cars: small cars have been selling at a premium in the United States in 1979, while large gas-guzzlers have been clogging dealers' lots. And in some countries, government regulations also require substantial improvements in the fuel economy of new vehicles. U.S. Government standards require cars sold in 1985 to travel an average of 27.5 miles per gallon of gasoline—double the mileage obtained by 1974 models. In Britain, where the average car already gets about 25 miles to the gallon, car manufacturers have voluntarily agreed to increase the fuel efficiency of their products by 10 percent over the next six years. West German car makers have agreed to make similar efficiency improvements.[55]

The strategy adopted by automobile manufacturers for meeting these fuel-efficiency standards is relatively straightforward: cars made over the next five years will be smaller, lighter, and slightly less powerful than today's models; although some will have diesel engines, most will still use gasoline. The car of the mid-eighties, in short, will not be radically different from the car of the seventies, and it will be designed to have a similar performance in terms of acceleration and ability to cruise at high speeds.

This should not be too surprising, and in fact is almost unavoidable. One problem is cost. Relatively minor style changes can cost hundreds of millions of dollars as assembly lines are retooled and it can take years to organize the production of new parts and supplies. General Motors claims, for example, that its new X-car—a front-wheel-drive model produced in 1979 that incorporates no radically new technology—took six years to design, develop, test, and produce at a total cost of $2.7 billion.[56] Reducing the weight of the new car fleet will thus require billions of dollars in capital investment. More fundamental changes in automotive technology would require many more years of development—too long to influence the nature of the automobile before 1985. Detroit thus has little room to maneuver in meeting the 1985 standards; it will essentially rely on proven technologies.

Whether government-imposed or industry-adopted, standards for fuel efficiency can improve overall fleet performance only gradually. Even

"While new cars in 1985 will be able to travel an average of 27.5 miles per gallon, the average for the total U.S. fleet will be considerably lower."

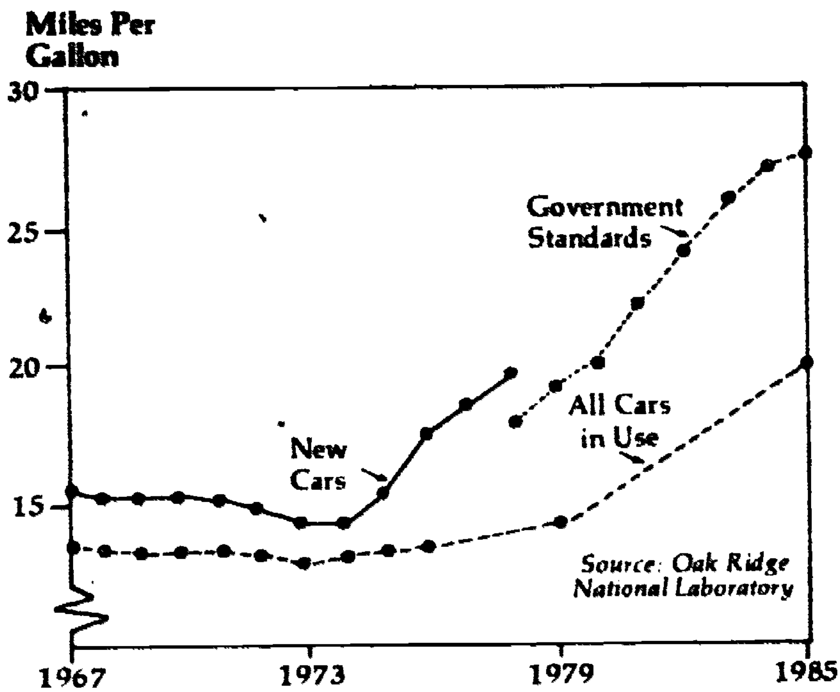

Figure 3: Fuel Consumption of U.S. Automobiles 1967-78, With Projections and Government Standards to 1985

if a new generation of more efficient vehicles could be produced quickly, it would take many years for the full impact to be felt. While new cars produced in 1985 will be able to travel an average of 27.5 miles per gallon, for example, the average for the total U.S. automobile fleet will be considerably lower, for there will still be many older, less efficient models on the road.[57] (See Figure 3.)

There is scope for improving the efficiency of the automobile at virtually every point from the engine to the tires. Less than 15 percent of the energy contained in a gallon of gasoline or diesel fuel is used to propel the vehicle forward. The rest is lost as heat, or is used to overcome engine and transmission friction or to power accessories such as power brakes, generators, and air conditioners.[58]

Many of these losses are unavoidable. It is impossible, for example, to run an engine without losing energy as waste heat. The laws of physics simply do not allow it. And there will always be losses in overcoming friction. But through better lubricants, more efficient transmission systems, and improved engine tuning, some of these
32 energy losses can be significantly reduced. To begin with, however, the greatest energy savings are likely to arise from reducing the weight and power of automobiles. Detroit is largely counting on such reductions to meet the 1985 standards.

The energy required to accelerate a vehicle and the energy lost in overcoming friction are roughly proportional to vehicle weight. Shaving 10 percent off the weight of a car, either by making it smaller or by replacing heavy materials with lighter substitutes, will result in a savings of about 7 percent in fuel consumption, according to a study by the U.S. Department of Transportation.[59]

American automobiles are prime candidates for weight reduction. On the average, they are more than 1,000 pounds heavier than typical European and Japanese cars, with some behemoths tipping the scales at close to 5,000 pounds. American car manufacturers are thus slimming down their products. General Motors cars have lost an average of 650 pounds each since 1974, and a further 700 pounds may drop off by 1985. Similar reductions have taken place in models turned out by Chrysler and Ford—the last two-and-a-half ton Lincoln Continental rolled off the production line in 1979, for example, and it will be replaced by a new version weighing 1,000 pounds less.[60]

Car manufacturers are counting on two other technologies already available to boost the efficiency of the current generation of automobiles: diesel engines and improved transmission systems. Diesels can provide 20 to 25 percent more miles to the gallon than can equivalent gasoline engines. The most efficient car on the road in the United States in 1979, for example, is the Volkswagen Rabbit diesel, which gets an average of 42 miles per gallon in combined city and highway driving. According to Dr. Peter Hofbauer, Director of Volkswagen's Advanced Automotive Power Systems Division, the company already has a five-passenger test vehicle capable of traveling 60 miles on one gallon of diesel fuel.[61]

Whether such dramatic improvements in efficiency will actually be realized in full-fledged production models remains to be seen, but the scope for improvements using diesel engines is clearly great. There are, however, drawbacks. Diesels tend to be dirtier and noisier than gasoline engines. At present, it seems they are unlikely to meet the U.S. emission standards for oxides of nitrogen that have been set for the early eighties. They also emit soot particles and, according to some reports, diesel exhaust fumes may contain carcinogens.[62] So far, no technological fixes like the catalytic converter are in sight for overcoming these problems, and they place a serious question mark over diesel technology in the next few years. The fuel efficiency of the diesel engine warrants a major research and development effort to deal with the pollutants connected with its use.

As for transmission systems, the three-speed automatic that is now a standard feature on American cars uses 10 percent more fuel than a four-speed manual system does. In other words, drivers of cars with automatic transmissions pay a 10 percent fuel penalty simply to avoid moving their hands and feet a few inches to change gears. The smaller, more efficient cars on the road today have reverted to four- or even five-speed manual transmissions. European and Japanese cars have always had such systems as a standard feature.

A considerable amount of effort is being spent on making automatics more efficient, however, and there are promising developments. To begin with, automobile manufacturers are concentrating on the development of four-speed models that incorporate a device, known as a torque-converter lock-up, that greatly reduces friction losses during highway driving. Such transmissions promise to be almost as efficient as current manual systems, and American car manufacturers hope to install them on about one-fourth of their cars by the mid-eighties.[63]

Farther down the road, the development of a radically new transmission, called the continuously variable transmission (CVT), may offer substantial fuel savings. A great deal of energy is now lost because of poor matching between engine speeds and engine loads. Increasing the number of gears helps to provide a better matching over a broad range of speeds, which is why shifting from three- to four-speed automatics has a high priority among car manufacturers. The CVT system would offer even greater improvements by allowing an engine to be run at its most efficient speed throughout an entire journey, with the power applied to the wheels through an infinitely variable set of gears. According to some estimates, such a system would improve fuel efficiency by 20 to 30 percent. Although CVTs have been under investigation since the fifties, they have so far been expensive and relatively unreliable. However, they offer considerable promise in the long term.[64]

Other important programs to raise the efficiency of the current generation of cars include improving lubricants to cut down losses through engine friction, using micro-computers to regulate fuel intake, and reducing wind resistance through better aerodynamic styling. Turbochargers—devices that use exhaust gases to ram the air-fuel mixture into the cylinders to improve combustion efficiency—are now being installed on some cars to increase the power of engines in relation to size. This enables the use of smaller engines to provide a given performance. And the Ford Motor Company is developing a fuel injection system for some of its models in the early eighties that promises substantial fuel savings.[65]

Raising the average efficiency of the new car fleet in the United States to 27.5 miles per gallon will have a significant impact on overall fuel consumption. According to a projection by the Congressional Office of Technology Assessment, gasoline and diesel fuel consumption will decline slightly from about five million barrels per day in 1975 to about 4.8 million in the mid-eighties, even allowing for an increase in both the number of automobiles and the total number of miles driven.[66]

Beyond 1985, the demand for automotive fuel will depend to a large extent on further improvements in fuel efficiency. While 1985 models will be able to travel almost twice as far on a gallon of gasoline as 1974 models, they obviously do not represent the ultimate in fuel efficiency. An international group of industrial, government, and academic experts on automobile technology, which met in Boston in February 1979, concluded that it should be technologically possible to boost the average efficiency of new cars to about 50 miles per gallon by the end of the century. Technological breakthroughs in areas such as high-temperature ceramic materials, improved lubricants, new transmission systems, and better aerodynamic design will be

"Far greater fuel efficiency could be achieved by matching vehicle power with actual requirements."

required, however, together with a further shift toward the use of lighter, stronger materials.[67]

The Boston meeting concluded that there are no magical technologies in sight that will replace internal-combustion engines in the near future. Although considerable research and development work is being done on Stirling engines and gas turbines, they are not yet remotely ready to be adopted as automobile engines and their efficiency is open to question. Hydrogen-powered vehicles have attracted some attention, chiefly because they would be nonpolluting and would not require oil, but hydrogen is an extremely expensive fuel that is difficult to store even in metal containers.

Electric vehicles offer a more plausible alternative, but the fundamental problems in battery technology mentioned earlier remain to be overcome. Even if such problems could be surmounted, battery-powered cars would not be spectacularly efficient in overall energy terms. If energy losses at power plants are taken into account, electric cars would travel only about 25 miles per gallon of oil equivalent, according to the U.S. Department of Energy.[68] Their chief advantage, however, is that if the electricity is generated in power plants that are not fueled by oil, battery-powered vehicles would not be competing for traditional automotive fuels.

If the internal-combustion engine is to remain the principal technology for the next few decades, how efficient could it ultimately be made? The answer will depend to a large extent on what will be required of tomorrow's automobiles. If they are designed to have rapid acceleration, a fast cruising speed, the ability to carry five or six passengers, and sufficient power to pull a trailer—all standard features of U.S. cars today—fuel economy is unlikely to reach more than 50 miles per gallon. Far greater fuel efficiency could be achieved by designing less powerful vehicles, and by matching vehicle power with actual requirements.

Most trips do not require the full power that large automobile engines are capable of delivering. Indeed, even though speed limits have been imposed in most countries, automobiles are still being designed to travel at speeds of more than 80 miles per hour. If cars were built to attain a maximum speed of, say, 65 miles per hour—faster than the current U.S. speed limit to provide some reserve power for passing—engine power and weight could be reduced substantially. Moreover, with lower average speeds, rapid acceleration would be less important when passing cars on highways. Performance, in short, should be equated with efficiency, not power.

36 Some Dutch students have built a vehicle that can get 2,070 miles to the gallon. Weighing just a few pounds, and powered by a tiny engine capable of producing a top speed of only about 10 miles per hour, it does not qualify as an automobile, but it does indicate the potential if fuel economy is made the chief criterion of vehicle design. Automobiles designed for city and highway driving would obviously be heavier and more crash proof, have better acceleration, and be required to meet pollution-control standards—all of which would raise fuel consumption. But a relatively low-speed automobile would be far more economical than the powerful vehicles available today. While such automobiles would be unable to provide the range of functions of today's cars, most of those functions are seldom required. For many people, it would make economic sense to own a small, efficient automobile for everyday use, and to rent a more powerful vehicle for those few occasions when increased power is required.[69]

Automobile manufacturers have been understandably reluctant to produce vehicles with reduced speed and acceleration because they fear that there would be a limited market for such automobiles. Yet large amounts of money are being sunk into the development of electric cars with just such characteristics. If there is a potential market for electric vehicles, there should likewise be a market for efficient gasoline or diesel-powered vehicles that can get 80 miles to the gallon. Cars that relied on internal-combustion engines would have the advantage over electric vehicles of unlimited range and a lower price.

Discussions of the technological potential for improving automobile efficiency tend to neglect the fact that efficiency can be improved dramatically by nontechnological means. Doubling the number of occupants nearly doubles a car's efficiency in terms of passenger miles per gallon, for example. And the adoption and rigorous enforcement of speed limits would not only result in more efficient driving habits, but would also eliminate the need for high-speed, inefficient vehicles. Public policies that encourage car pooling and similar moves can thus have as much impact as technological changes do on automobile efficiency. Their impact, moreover, is immediate.

Alternatives to the Automobile

One of the principal selling points of the automobile is the mobility it provides. Unfortunately, as the number of cars on the road increases, particularly in urban areas, this advantage begins to disappear. Excessive reliance on automobiles can lead to extreme congestion, cause dangerous levels of air pollution, and become a serious drain on public coffers—all substantial reasons for considering alternatives. But the one reason that is beginning to dwarf all others is the prospect of scarce and costly automotive fuels.

Public transportation is naturally the centerpiece of most alternative schemes. But it is important to realize that public transport is not an automatic panacea for the fuel-efficiency ills of automobiles. Though well-designed bus and rail networks have the potential to achieve levels of efficiency far above those of today's cars, the reality sometimes falls short.

Buses have several inherent efficiency advantages over automobiles, including the use of diesel engines, a lower weight and less wind resistance per seat, and a moderately sized engine that is designed to give adequate performance but not to accelerate rapidly at the whim of the driver. Trains are also blessed with efficient diesel or sometimes electric engines and have even better weight and wind resistance advantages than buses have. These characteristics give urban buses and trains a potential fuel efficiency when fully loaded of over 150 passenger miles per gallon. Outside cities, buses can get well over 200 and trains close to 400 passenger miles per gallon.[70]

In the United States, urban bus and subway systems approach these levels of efficiency during rush hours, but fall well below them when nonpeak hours are included in the calculation. Average fuel efficiencies of 40 passenger miles per gallon appear to be the rule in all but the most heavily used systems. The public transit systems in European and Japanese cities probably come much closer to potential efficiencies. For travel between cities, trains in Europe and buses in the US at least begin to approach potential fuel efficiency levels. Greyhound buses in the United States, for example, achieved 140 passenger miles per gallon in 1978. Unfortunately, the same is not true of the heavily subsidized U.S. Amtrak service, which averaged only 40 passenger miles per gallon that same year.[71]

Under some circumstances, the automobile can match or exceed the efficient uses of fuel noted above. Some of today's small cars, when carrying four people, can manage 100 passenger miles per gallon in the city, and up to 180 between cities. But American commuters drive inefficient cars and on the average they carry only 1.4 passengers per car, so they achieve a meager 16 passenger miles per gallon.[72] The important point is that the efficiency of both public and private vehicles depends on how they are used. Trains and buses can exceed the efficiencies of even the most economical automobiles—but only if the service is cheap and convenient enough to attract passengers.

Trains and buses do not, however, have a monopoly on fuel economy. Vans or minibuses when fully loaded are capable of nearly as much fuel efficiency as buses—some 150 passenger miles per gallon by some calculations. Such vehicles obviously have great potential for offering some of the conveniences of the automobile along with the fuel economy of the bus. Whether used in private car pools or operated by local transit authorities, the minibus may be an attractive alternative for many commuters. In the Philippines, for instance, 30,000 "jeepneys," a variation of the minibus, carry up to ten passengers along fixed routes.[73]

The fortunes of public transportation over the last quarter-century have unfortunately not reflected its fuel efficiency advantages. In fact public transport has suffered a nearly universal demise that has been as dramatic as the simultaneous automobile boom. In the six years since the 1973 oil price rise, the use of public transportation has begun to grow slowly, but growth in car use through 1978 was still outpacing that of trains and buses.

In the United States, urban public transit reached its historical peak during World War II, when 19 billion passengers annually rode the nation's streetcars, subways, and city buses. At the close of the war, transit use abruptly declined by one-quarter, and then followed a steady downhill path for 28 years. The streetcar, which once ac-

"Twenty-one million riders per day now travel on Tokyo's public trains, subways, and buses."

counted for one-third of all passengers, disappeared almost entirely. By 1973, overall bus and rail ridership had fallen to 5.3 billion, less than one-third the 1945 level. Since then, public transit use has begun to climb, albeit slowly. By 1979, U.S. ridership was 20 percent above the 1973 level, yet this is still lower than even the moderate levels of the mid-sixties. Today 80 percent of American commuters who live in cities travel by car, and only 13 percent use public transport.[74]

In European cities, where people on the whole rely much more on public transportation than Americans do, major declines in transit use have also occurred. A recent OECD survey of medium-sized cities found that ridership per person in most areas had decreased between 25 and 40 percent from 1950 to 1974. Larger cities with relatively dense central areas have had better success at maintaining and, in some cases, expanding their transit systems. Yet even in these cases the record is mixed. In Copenhagen, for instance, over the last 25 years a steady 50 percent of the trips made in the downtown area have been on public transport. Meanwhile, however, private car use in that part of town has tripled, and now accounts for over 30 percent of trips.[75]

Japan, despite its recent infatuation with the car, is the world leader in public transit. Subway use in Tokyo has increased tenfold since 1955, while commuter railroads have tripled their ridership. Twenty-one million riders per day now travel on Tokyo's public trains, subways, and buses, straining even this very good system close to the breaking point. Public trains there are so fully loaded with commuters that trained "pushers" are necessary to achieve sardine-like concentrations of passengers before the doors are closed. Only 7 percent of the city's workers commute by private automobile; though commuters in other Japanese cities have not so thoroughly abandoned their cars, most are not far behind.[76]

Public transportation between cities and within rural areas has never been as widespread nor as efficient as that in urban areas. And it too has been on the wane. Automobile use between American cities has increased 75 percent since 1960, and now constitutes 85 percent of intercity travel. Air travel has grown even more rapidly, and commands 12 percent of between-city traffic, leaving trains and buses with a meager 3 percent of the total—most of it by bus. Intercity bus service does provide a transportation alternative for a great many communities, both large and small, but at standards of convenience that are woefully short of those provided by the car. Even the bus, however, dwarfs the passenger train contribution to travel between cities in the United States. Amtrak, despite its wealth of publicity, provides a significant service along only a handful of heavily traveled corridors.[77]

In Europe, intercity travel by train is much more prevalent, accounting for close to one-quarter of such traffic. In contrast to the United States, trains carry far more passengers than planes do. But Europe, like the United States, has been on a highway-building spree, and today more people are using automobiles for business and recreational trips than ever before. In recent years, two-thirds of European travel between cities has been by car.[78]

In developing nations, as opposed to Western ones, there is no lack of demand for public transportation. This high level of demand is unfortunately not reflected in the quality or quantity of service provided. Rail systems have been constructed in only a few Third World cities, and though passenger traffic by bus is often twice that by car, service is in most cases entirely inadequate. There are rarely enough buses for a given population, and those that are in operation often break down because of obsolescence and lack of maintenance. In addition, massive traffic tie-ups caused by private automobiles slow buses down just as much as they do other cars.[79]

In recent years the need for better public transportation has finally begun to receive more than just lip service, as national and local funds in many countries have been put into a variety of systems. However, it is clear that in few cases have plans for a better system been integrated into a broader effort to provide viable means of transportation over the long haul. Today there are abundant examples of transport plans that have failed to provide convenient service for a sizable segment of the population, or even to alleviate congestion.

The Bay Area Rapid Transit (BART) system in San Francisco is a case in point. BART is highly mechanized and speedy—on the cutting edge of transit technology. Yet despite the great planning and expense that went into this system, it is capable of servicing only 5 percent of the area's population. Commuting patterns are sufficiently random that it is difficult to serve a large segment of the area's commuters along a few well defined routes. The Washington, D.C., subway system, another recent attempt at efficient rail service, is better designed than BART, and also has the advantage of serving a more concentrated metropolitan area. However, even the "successful" Washington Metro subway will never be able to serve the majority of commuters without an extensive network of buses to bring people to the stations. And, like BART, Metro has managed to quench only slightly the city's formidable thirst for gasoline.[80]

Mexico City also constructed a rail transit system during the late sixties—one of only a handful of Third World cities to attempt such a project. It was a bold step, considering that Mexico City is the most rapidly growing urban agglomeration in the world. The system is relatively small yet expensive, covering 45 kilometers and requiring considerable government revenues in order to keep fares affordable. Within a year of its inauguration, the congestion in the subway cars was as bad as that in the streets. Mexican planners now recognize that this ambitious system has no hope of slowing the growth of an automobile fleet that is expected to double in less than ten years, and that will absorb a large portion of Mexico's newly found wealth of oil.[81]

The mass-transit legacy of the last ten years clearly indicates that huge investments in new transit systems are unlikely in themselves to cause a wholesale reduction in auto usage. Only if such systems are accompanied by a combination of traffic restrictions and financial incentives to encourage drivers to leave their cars at home are substantial improvements likely.

As governments begin to focus on energy-conserving yet convenient alternatives to the automobile, the bicycle must be placed near the head of the list. Requiring no petroleum-based fuel, and nearly as fast as the car for short urban trips, the bicycle's attraction is obvious. Furthermore, bikes can travel on existing roads and do not need the major capital expenditure of new mass-transit systems. However, the bicycle is unlikely to fare well without government encouragement, as the experience in many countries since World War II has shown. Increasing levels of automobile traffic have encouraged suburban development in areas that are too distant from downtowns to be reached by bike. The great number of cars on the roads has also made bicycle riding quite dangerous.

The bicycle, like the car, was developed in the late nineteenth century, and has long been overshadowed by its more glamorous and powerful cousin. In the early part of this century, the bicycle became an accepted means of travel in many European and East Asian cities. Yet between 1950 and 1973, cycle traffic was reduced to less than half its earlier level in many of these cities. Rising incomes and cheaper cars encouraged many urbanites to switch from pedals to a steering wheel.[82]

Since 1973, however, people's seemingly rational decisions to give up their bicycles in the fifties and sixties have been appearing less than visionary. In the last five years, consumers throughout the world have been buying bikes in unprecedented numbers. In both North America and Europe, bicycle use is on the rise for the first time since World War II; use has also increased rapidly in the Third World, where the bicycle has been important for decades.

In recent years, sales of bicycles have exceeded those of automobiles in many countries. In the United States, 103 million bicycles were sold over the last ten years, compared with 102 million cars. In West Germany, bikes have outsold cars by a much wider margin. The British Transport and Road Research Laboratory reports that 20 years of decline in the use of the bicycle was arrested in 1974 and that its use increased some 25 percent during the next three years. The Netherlands, a country favored by a relatively mild climate and flat terrain, now has nearly as many bicycles as it does people. Each morning some five million men, women, and children depart for work, school, or shopping on bicycles. In some Dutch cities, nearly half of all commuting is by bike.[83]

Paralleling the recent popularity of the bicycle has been that of the closely related moped. As its hybrid name implies, the moped is a cross between a motorcycle and a bicycle—retaining some of the features of each. A typical moped weighs less than 100 pounds and can be powered with a one- or two-horsepower engine as well as by pedal. Capable of perhaps 30 miles per hour, the moped is used by many people who seek fuel economy and the convenience of the bicycle, but who lack the physical stamina to pedal long distances at a rapid pace.[84]

"In the United States, 103 million bicycles were sold over the last ten years, compared with 102 million cars."

Mopeds have been widely used in Europe since the fifties, but only recently have they become popular in other parts of the world. Today there are between 22 million and 25 million mopeds worldwide—half of them in Europe and four million in Japan. Growth since 1974 has been rapid in these areas, but has also spread to North America and to some Third World countries. There were only 50,000 mopeds in the United States before 1975; current projections are that one million will be in use by early 1980, and between three and five million by the mid-eighties.[85]

Bicycles and mopeds clearly have an important role to play, particularly in urban and suburban areas where short commuting and shopping trips represent the main transport needs. In the US as a whole, 80 percent of automobile trips are shorter than ten miles, a quite reasonable distance by bicycle or moped. In modern suburbs, a dearth of public transport and a high proportion of local shopping trips have encouraged particularly rapid growth in the use of bikes and mopeds. As one moped enthusiast says, "why use a gallon of gas to buy a gallon of milk?"[86]

Among the many laudable attributes of the bicycle and moped, fuel efficiency has caught the eye of most recent converts. Mopeds average 135 miles per gallon—three times as much as the most efficient cars. One recent study estimated that the bicycle could travel 1,000 miles per gallon of gasoline equivalent, but its real attraction is that gas is not required at all. An often neglected renewable energy resource—the calories contained in food—supplies all the needed power. The bicycle is in fact the most energy efficient means of transport ever known, more than tripling the efficiency of walking. In addition, bikes and mopeds address many of the other problems associated with the automobile—air pollution, congestion, and urban space constraints.[87]

In the Third World, the large urban populations expected in the future make the space and congestion arguments for bicycles and mopeds overwhelming. Road systems will simply never be able to handle the quantities of automobiles that would be needed to transport so many people. In addition, capital expenditure, always a problem in the Third World, would be greatly reduced with two-wheeled transportation as opposed to either the automobile or mass transit. Finally, very few developing countries have domestic petroleum reserves and so will be able to ill afford the fuel inefficiency of automobiles as industrial nations bid up the price of oil.

As with mass transit, encouragement of bicycle and moped travel is just beginning to be a major focus of public policy. Until recently, the rapid rise of the automobile and the simultaneous demise of other means of transport were in effect subsidized by government policies. Since 1960, vast amounts of public money have been devoted to street and highway building, including the development of extensive high-speed expressways in most industrial countries. Few nations have devoted such amounts to train or bus services, let alone to the construction of bikeways. In addition, the lack of restrictions on inner-city automobile travel has induced motorists to clog the streets to a point where bicycle and bus traffic is severely impaired. The closing of certain streets to automobiles would make the bus, bicycle, and moped all more attractive.

In general, European cities have done the most to limit automobile traffic to reasonable levels—largely out of necessity. In Europe, twentieth century growth has often been superimposed on medieval street design. And even the more recently designed cities are relatively densely settled because of space limitations. Many have found it desirable to restrict the movement of automobiles severely, but to allow easy access for buses and bicycles.

Both Bremen, West Germany, and Göteborg, Sweden, have divided their downtown areas into "cells." Within each cell, traffic is unrestricted, but automobiles cannot cross from one cell to an adjacent one. Loop roads do permit travel around the central areas. The result has been significant rises in the use of public transit within the cities and lower levels of congestion. A few cities in France, Italy, and the Netherlands have recently adopted similar schemes.[44]

The setting aside of streets for pedestrians has been a popular means of limiting automobile traffic for some time. Dozens of European cities introduced such schemes during the sixties and seventies, mainly to reduce congestion and to revive the inner city. Many medium-sized cities as well as larger ones, such as Copenhagen and Vienna, have found that these pedestrian streets greatly improve mobility and increase the attraction of downtown areas. And much to the delight of shopkeepers, business has generally improved—in some cases dramatically. The pedestrian streets have generally been limited to a few kilometers in length; nonetheless they are a step in the right direction. When combined with effective mass transit, such schemes can make large sections of cities viable without the automobile.[89]

Another approach pioneered in Europe is the separation of buses and bicycles from automobile traffic. The usual result is that bus and bicycle travel becomes speedier and more convenient, and automobile travel less so. In England, the university towns of Oxford and Cambridge have excluded automobile traffic from certain streets. This does not entirely prevent cars from entering central areas, but it does serve to discourage them. Other cities have proceeded more tentatively in reserving particular lanes for buses, streetcars, and bicycles, in some cases only during peak traffic hours. London, Paris, and Washington, D.C., have variations on this scheme. In these cases, the efficiency of public transit has been improved, but automobile traffic has not been substantially reduced.[90]

From the cyclist's point of view, there is something to be said for constructing special bike paths from which buses are excluded as well. In Davis, California, some 28 miles of bike paths have been built in the past few years and it is estimated that cycling accounts for one-quarter of all travel there. In Vasteras, Sweden, 70 bicycle tunnels were recently constructed at intersections and have vastly improved the convenience and safety of cycling. And West Germany is considering the construction of bike paths along 30 percent of all city streets.[91]

Many communities have begun evaluating even more substantive programs to restrict automobile traffic in cities. The possibility of largely excluding cars from extensive parts of urban areas is one that has crossed the minds of many planners. Licenses could be granted to people who live in the restricted area or who operate delivery trucks and other commercial vehicles. Some of these licenses could be sold at a steep price, with the proceeds going to public transport. Obviously, such a program would have to be accompanied by an extensive and flexible transit service, with large parking facilities outside the restricted area. It would entail considerable restrictions on the freedom of car drivers, and so far few communities have been able to summon the political will to implement such a system.

The largely urban nation of Singapore is a most notable exception. Since 1975 a license has been required to enter the inner city by car or taxi between 7:00 a.m. and 10:00 a.m. Licenses cost $1.50 per day—which reduces the appeal of city driving. Singapore's license plan reduced urban congestion and has attracted much attention from the World Bank as well as from local governments around the world. Even though downtown traffic has been reduced by two-thirds, mobility has not been substantially lowered.[92]

Singapore has pointed the way toward the type of comprehensive program promoting alternatives to the automobile that is going to be essential in the years ahead. Currently, many nations have stepped up the funding for mass transit and for bikeways, but only in a piecemeal fashion. Clearly, if the transition to alternative means of transportation is to occur before gasoline becomes debilitatingly scarce and expensive, the process of change will have to be more vigorous and rapid. In the past, neither cyclists nor mass-transit riders have been able to muster a sufficient political constituency to force such innovation. One of the encouraging aspects of the oil crunch of 1979, however, has been the increasing numbers and strength of such groups. Mass-transit ridership and bicycle use are booming, and, as a result, comprehensive plans to limit automobile traffic and to promote alternatives are finally receiving some attention.

The Difficult Policy Choices

The changing outlook for the automobile presents government officials with complex political choices and individuals with difficult personal decisions. Automobile industry projections, national economic plans, and consumer hopes are all based on the production of more and more cars. But these projections, plans, and hopes now appear unrealistic.

Two fundamental trends are shaping the future of the automobile. The first is the leveling off of world oil production. The second is the projected increase in the most essential uses of oil—to produce food, to heat homes, to run factories, and to power trains, trucks, and buses. As these demands press against fixed supplies of petroleum, they will leave less and less fuel for cars.

"The question is no longer whether fuel supplies for the automobile will decline, but when and how rapidly."

Although gasoline supplies have expanded rapidly throughout most of the postwar period, this pattern has been recently interrupted. And there is little reason to expect that the long-term trend of rapid growth will ever be resumed. For many oil-importing countries hard hit by the recent price rises, the question is no longer whether fuel supplies for the automobile will decline, but when and how rapidly.

As supplies of petroleum tighten in the years ahead, political leaders will constantly be forced to reestablish priorities in its use. Experience to date indicates that most governments, regardless of ideology or stage of development, have a common set of priorities—priorities that are shaped by such basic human needs as the production of food and the provision of heating and cooking fuel.

In the United States, the government's priorities in fuel allocation became clear in the spring of 1979 when there was a shortage of diesel fuel, a fuel used both in trucks and in farm tractors. The Department of Energy had little choice but to give the agricultural sector first claim on the scarce fuel supplies. As a result, farmers were able to plant their crops on schedule; but truckers were piqued because of the lower priority accorded their needs, and they went on strike. Variations on this theme are certain to be repeated in country after country as essential demands for oil press against limited supplies.

For many Third World countries, food production is likely to have the first claim on oil supplies. Their demand for food is projected to double over the next generation, yet the principal techniques for expanding food output—mechanization, irrigation, and the use of chemical fertilizers—are all energy-intensive. The basic fuel for tractors and for irrigation pumps is invariably in the form of petroleum products. Thus for many developing countries, particularly those now beginning to mechanize, vast increases in agricultural energy use are projected as food needs soar between now and the end of the century. In China, where the mechanization of agriculture is one of the "four modernizations" now being officially pursued, fossil fuel use in crop production is expected to quintuple as the country both mechanizes its agriculture and intensifies crop production.[93] Such growth in the demand for energy—principally petroleum—will be the rule, not the exception, in the Third World countries attempting to feed their expanding populations.

Job creation will also place heavy demands on available oil supplies over the next few decades. New entrants into the world job market by the year 2000 will approach 700 million, more than in any comparable period in human history.[84] Providing jobs for these people will require the construction of record numbers of factories, all of which will require energy in some form. Many will use petroleum either as an energy source, as a raw material, or as both.

A substantial share of the world's petroleum supplies is used to heat homes, offices, and factories in the north temperate zone, a need that ranks high on the scale of governmental priorities. Long gas lines in the United States in the spring and early summer of 1979 were in part due to Washington's decision to set aside enough petroleum to ensure adequate supplies for the following winter's home-heating needs. Reducing automobile use is inconvenient. But running out of home-heating fuel where winters are severe can lead to hardship and sometimes death.

Within the transport sector itself, the automobile occupies the lowest position on the totem pole of priorities. When forced to choose between freight and passenger service, freight must be given priority, for the movement of raw materials and goods in the arteries of commerce is essential to the functioning of an economic system. And when it comes to passenger travel, governments must expect pressure to support the more efficient forms of transportation—buses, trains, mopeds, and bicycles. The pressures to use scarce liquid fuels ever more efficiently are bound to increase.

The implications for the automobile of having a low priority compared with the other petroleum claimants are potentially severe. For example, in a country that imports its oil and uses 20 percent of the total supply to run its cars, an abrupt 10 percent reduction in overall supplies would have to be absorbed largely by automobiles. While there are opportunities for increasing the efficiency of oil use in virtually all sectors, any government would find it difficult to reduce significantly the allocation to such vital areas as food production, industrial use, or freight transport. Reductions that proved disruptive in such areas would be economically disastrous and politically suicidal.

Although most governments have historically encouraged the movement toward automobile-centered transport systems—and still do—the recent oil shortage has led many to restrict the automobile's use, creating a curiously ambivalent attitude toward it. Even while they continue to invest public funds in highway construction and to license the construction of new auto assembly plants, more and more governments are discouraging automobile use directly or indirectly. Some restrict the availability of gasoline; others, the use of the automobile itself.

Scarcely a day passes without the international press carrying news of some additional restriction on the use of cars—the adoption of gasoline rationing in Tanzania, a lowering of highway speed limits in Portugal, or the establishment of "bus-only" lanes on Los Angeles freeways. National governments in Western Europe have used taxes to encourage gasoline conservation, with the tax often exceeding the price of the fuel itself. And at the local level, some city governments use taxes or parking fees to discourage driving in the inner city.

In the centrally planned economies of Eastern Europe and the Soviet Union, where the cost of gasoline is fixed by government, prices have jumped by 30 to 100 percent over the past year or so. On March 1, 1978, the Soviet leadership announced an overnight near-doubling in the price of gasoline. In Bulgaria and East Germany, gasoline prices have been raised to $3 or more per gallon.[95] These policies in centrally planned economies indicate a decision to discourage both the short-term use of gasoline and the long-term evolution of an automobile-centered transportation system.

When the supply of gasoline is particularly tight, governments often try to reduce its use by restricting the time of purchase, which is, in effect, a form of "nuisance rationing." Service stations in Brazil and Japan are routinely closed on Sundays. When U.S. gasoline supplies were uncommonly tight in early 1979, several of the more populous states—California, New Jersey, and New York, among others—permitted car owners to purchase gasoline only on odd or even days, depending on the last digit of their car's license number.[96]

Policies to discourage the use of automobiles have been adopted in a broad range of countries. In those Third World countries where all passenger cars are imported, import policies are being used to discourage automobile ownership. Kenya, for example, now requires a large deposit on new cars. Where prices are fixed by governments, as in the centrally planned economies, automobile sales can be influenced directly. In July 1979, the Soviet Union again raised automobile prices, already among the highest in the world. Sri Lanka has introduced carless Sundays. Israel is considering a mandatory carless day each week, with the day to be selected by the owner and displayed on a windshield sticker. In a desperate effort to conserve fuel use, Bulgaria has gone even further, restricting automobile use to odd or even days.[97]

One of the great risks in the growing dependence on automobiles is that the purchasing power of affluent motorists, wherever they are, will drive oil prices upward until social and economic development programs are brought to a standstill in the poorer countries that lack indigenous oil resources. The loss of economic momentum could be unsettling, to say the least, but the loss of hope that would follow could be devastating. In an oil-short world, the basic human needs development strategy now being advocated by the international development community and an ever-growing global auto fleet may be in conflict. It is against this backdrop that the worldwide need to move toward more fuel-efficient transport systems should be considered.

As the global demand for oil outstrips supply at prevailing prices, pressures could mount for an international allocation system. Oil normally has been allocated internationally according to purchasing power, usually going to the highest bidder. But if such a system pushes prices to a point where poor countries cannot obtain enough oil to meet their basic needs, then these countries may appeal to the oil-exporting nations for a formal allocation system. This would be, in effect, an international system for rationing scarce supplies among importing countries. And Western nations may find that those who supply the oil will not permit the auto-centered transport systems in the wealthy industrial countries to siphon fuel away from the food-producing sector in the Third World.

Among the industrial countries themselves, there have been pressures by various nations to make adjustments. At the June 1979 Tokyo summit conference of the principal Western industrial powers, for

"The basic needs development strategy and its ever-growing global auto fleet may be in conflict."

example, French and German leaders pressed President Carter to reduce U.S. oil imports. When asked to comment on American efforts to reduce oil consumption, French President Valery Giscard d'Estaing replied, "They haven't started."[68] As more countries realize that U.S. cars account for half of all gasoline used in the world automobile fleet, because they are so inefficient and because public transportation is so poor, international pressures to change are certain to intensify. Even within the United States, the realization that gas-guzzling cars contribute disproportionately to gasoline shortages, and indirectly to long waiting lines at service stations, could lead to pressure to ban their manufacture.

Governments that turn to alternative liquid fuels—whether from energy crops, coal, or oil shale—will often face difficult political choices. A commitment to any of these alternative fuels promises to alter the relationship between the food and energy sectors. Historically, the energy sector supported the food sector by providing the power for various agricultural activities. Now this relationship is changing. As demands converge, the two sectors are beginning to compete for the same resources. In the western part of the United States, for example, the production of synthetic fuels from either coal or oil shale will require vast amounts of water, water that often will be diverted from agriculture.

As energy crops, such as sugar cane, manioc, or corn, become more important sources of alcohol for automotive fuel, affluent automobile owners will begin to compete with low-income food consumers for the same land, water, fertilizer, and other resources. Whether an elevator full of grain in North America goes to a feedlot for livestock production, to a food-deficit country for human consumption, or to a distillery to produce automotive fuel will depend largely on relative purchasing power. Such a situation could force a choice between a limit on the use of the automobile among the rich and rising malnutrition and reduced life expectancy among the poor.

In addition to the development of alternative fuels, the development of a more fuel-efficient car will be essential for preserving a major role for the automobile. What is needed in a fuel-scarce world is a vehicle that can be driven 60, or perhaps even 80, miles on a gallon of fuel. Such a vehicle, which appears to be within the range of modern technology, would not only stretch fuel supplies but would also help keep the cost of running a car at an affordable level as gasoline prices move into the $3–$5-per-gallon range in more and more countries.

Yet another area where effective action could help keep cars on the road is the substitution of nonliquid energy sources for petroleum wherever feasible. For example, the use of solar collectors for home-heating could reduce the use of heating oil, a refinery product that so closely resembles diesel oil that they can sometimes be used interchangeably. How rapidly substitutions in this direction progress will depend in large measure on governmental programs and priorities.

With oil supplies becoming uncertain, with gasoline prices rising to unheard-of levels, with only negligible amounts of alternative fuels in prospect in the near future, and with governments imposing restrictions on auto usage, consumer interest in the automobile is weakening. Car sales in 1979 are falling sharply, much as they did in 1974 following the first oil shock. With a global recession in prospect for 1980, sales could drop even further, as they did in the recession year of 1975.[99]

While the world auto production outlook for the next year is reasonably clear, the long-term outlook is less so. The rapid growth in automobile production of some 6 percent per year that characterized the period from the end of World War II through 1973 has clearly ended. But whether the new trend will be one of much slower growth, of leveling off, or possibly even of declining production remains to be seen. Annual fluctuations over the next several years may make it difficult to determine the long-term trend.

The demand for new automobiles comes from two sources: people replacing aging vehicles, and people buying cars for the first time. Since 1971, world automobile sales have fluctuated between 26 and 31 million vehicles per year, showing only a slight upward trend. Either people have been hanging on to their cars longer, or potential new car buyers have been delaying their purchases. If sales remain within this range for a few more years, there will be a growing number of aging cars in the world's fleet. If the global economy improves, this would increase demand for new cars as people need to replace their old ones. But a prolonged recession or a shrinkage in gasoline

"Unless consumers exercise great care in buying automobiles, they may end up with a vehicle for which fuel is not available."

supplies could continue to depress demand, bringing growth in the world car fleet to a halt.

As the automobile loses some of its luster, attention will initially be focused on the automobile manufacturers and associated industries. In late 1979, assembly-line workers were being laid off in record numbers in the United States. Automobile companies such as Chrysler and Alfa Romeo were in financial difficulty.[100] Serious as these problems are, they should not be viewed in isolation but rather as part of a much broader process—the redesigning of an economic system that was set up to run on $2-a-barrel oil so that it will continue to function smoothly when oil or its equivalent reaches $40 a barrel.

There is a risk that the momentum of recent historical trends will lead to excessive investment, both public and private, in cars and their associated industries and transport systems. The continuing heavy investment in roads and highways, now common to so many societies, could lead to the construction of many that will never be fully used. Automobile companies would do well to exercise great caution in building any more assembly plants until the impact of shifting public priorities and rising fuel costs can be more fully assessed. And unless consumers exercise great care in buying automobiles, they may end up with a vehicle for which fuel is not available or that is too inefficient in its use of fuel to be economical.

Among the factors influencing the automobile's role, one of the most difficult to evaluate is the change in public attitudes as oil shortages become more critical. In Denmark, where public transport is an important component of the national energy conservation campaign, automobile use is being severely restricted in metropolitan areas not only by high gasoline prices and stiff parking fees, but above all, as one observer reports, "by public attitudes, which may soon render the ownership of (automobiles) both economically and socially unacceptable." In Sweden, a study by the Prime Minister's Office of Future Studies has recommended that the use of the private automobile be phased out in urban areas. It suggests funneling resources into a greatly improved and expanded public transportation system that would be augmented by an expanded fleet of rental automobiles for weekend excursions and other special trips.[101]

In the United States, automobile sales are down and travel habits are changing. Ridership on public transportation has turned sharply upward in 1979. Motorists are leaving their cars in record numbers as public transportation is upgraded and as gasoline prices climb. The American Public Transit Association reported that July 1979 was the twenty-fourth consecutive month of increasing use of public transit.[102] Perhaps for the first time since Henry Ford began mass production of the automobile over a half century ago, there are faint signs that the love affair with the automobile is waning.

A potential decline in automobile production and numbers does not necessarily mean less personal mobility. Those cities in which mobility is greatest are not those with the most automobiles, but those with the best public transportation systems. After a point, more cars in an urban setting can lead to less mobility, not more. In many cities, the channeling of government revenues into public transport and the construction of bikeways will lead not only to greater mobility but to cleaner air as well. The shift from automobiles to some of the more attractive alternatives could in fact become a two-way process: better public transportation could entice people from their cars while continuously climbing gasoline prices help push them from behind the wheel.

Assessing the future of the automobile is a complex undertaking, one that does not lend itself to simple analyses or to clear-cut answers. Some of the forces influencing its future are economic. Some are technological. And some are psychological and political. Among the economic forces shaping the auto's future are the slowing economic growth, accelerating inflation, and continuously rising oil prices that are in prospect for the eighties. On the technological front, the potential for designing a more fuel-efficient car and for developing alternative fuels holds the key. For the foreseeable future, the strength of the emerging "depletion psychology" in principal oil-producing countries, combined with the priorities established in the use of oil by governments everywhere, will largely dictate the availability of fuel for automobiles.

The first "oil shock" was a warning tremor; the second indicates the time of adjustment has arrived. These shocks do not signal the demise of the automobile but they do suggest a marked slowdown in the "automobilization" of the world. Until quite recently, virtually all countries were moving toward auto-centered trarsport systems. The United States had reached such a point more than a generation ago. Western Europe, several Latin American nations, and a scattering of countries elsewhere now also rely primarily on cars for personal transport. In some of these auto-dependent countries that rely on imported oil to run their cars, the pressures to move toward fuel-efficient forms of transport may soon diminish the reliance on the automobile.

In Eastern Europe, the Soviet Union, and most of the Third World, the movement toward automobile-centered transport systems has been slow. Although some further increase in car us ge is in prospect, the emergence of transport systems dominated by the automobile is not likely in these countries. For many societies it was a dream and it may well remain so.

The depletion of the earth's oil reserves is altering the outlook for the automobile. Both the role and the design of cars are changing. These should be seen not as isolated changes but as part of a fundamental worldwide adjustment to a scarcity of petroleum.

Notes

1. The 1978 figure is the authors' estimate based on data from Motor Vehicle Manufacturers Association of the United States (MVMA), *Motor Vehicle Facts and Figures, 1978* (Detroit: 1978).

2. For a good discussion of early developments in car technology, see Congressional Research Service, prepared for the Committee on Public Works, United States Senate, *History and Future of Spark Ignition Engines* (Washington, D.C.: Government Printing Office, 1973); and Gerald Bloomfield, *The World Autom^tive Industry* (North Pomfret, Vt.: David & Charles Inc., 1978).

3. MVMA, *World Motor Vehicle Data, 1978* (Detroit: 1978).

4. *Ibid.*

5. Japan Automobile Manufacturers Association, *Motor Vehicle Statistics of Japan, 1978* (Tokyo: 1978).

6. Robert U. Ayres, for Oak Ridge National Laboratory, *Worldwide Transportation/Energy Demand Forecast: 1975-2000* (Springfield, Va.: National Technical Information Service, 1978).

7. MVMA, *Motor Vehicle Facts and Figures.*

8. International Road Federation, *Road and Motor Vehicle Statistics for 1977* (Washington, D.C.: 1978).

9. Wilfred Owen, "Automobiles and Cities: Strategies for Developing Countries," in Ralph Gakenheimer, ed., *The Automobile and the Environment: An International Perspective* (Cambridge, Mass.: MIT Press, 1978).

10. Marcus Franda, "Alternative Energies and the Renewal of India," *Common Ground*, Winter 1978.

11. MVMA, *Motor Vehicle Facts and Figures.*

12. Japanese figure from Japan Automobile Manufacturers Association, *Motor Vehicle Statistics*; West European figure from "Automobiles: Challenge Facing European Manufacturers," *European Report*, October 21, 1978; French figure from Wilfred Owen, *The Accessible City* (Washington, D.C.: Brookings Institution, 1972).

13. World figure from Nicholas Valery, "The Age of Maturity," *The Economist*, March 10-16, 1979; U.S. figure from MVMA, *Motor Vehicle Facts and Figures*; West European figure from "Automobiles: Challenge Facing European Manufacturers"; "Driving Takes Quarter of Income, Study Says," *Washington Star*, June 25, 1979.

14. Bernard M. Chatelin, "Pattern of Transport in Developing Countries and Impact of the Energy Sector," World Bank, unpublished, October 1978; Valéry, "The Age of Maturity."

15. MVMA, *World Motor Vehicle Data.*

16. "Soviet Autos Get on the Road, But They Can't Overtake Much," *World Business Weekly*, February 19, 1979; South Korean figure from Bernard M. Chatelin, World Bank, private communication, June 12, 1979.

17. Rhys Jenkins, "Multinational Corporations and the Denationalization of Latin American Industry," Discussion Paper, University of East Anglia, England, October 1976.

18. Organisation for Economic Cooperation and Development, *Interfutures* (Paris: 1979).

19. U.S. figures from Office of Technology Assessment, *Changes in the Future Use and Characteristics of the Automobile Transportation System* (Washington, D.C.: 1979); world and European figures estimated from refinery outputs given in Department of Energy, *International Petroleum Annual 1977* (Washington, D.C.: 1979) with adjustments for composition [illegible] transportation fleets.

20. Youssef H. Ibrahim, "Behind Iran's Revolution: Too Much Spending, Too Soon," *New York Times*, February 4, 1979.

21. Alan Riding, "Mexico's Oil Won't Solve All the Problems," *New York Times*, February 4, 1979.

22. "Iran to Halve Its Oil Output," *New York Times*, March 9, 1979.

23. Oil production statistics from *International Petroleum Encyclopedia* (Tulsa, Okla.: Petroleum Publishing Co., 1978).

24. Paul Lewis, "OPEC Reaffirms Its Economic Power," *New York Times*, March 28, 1979; "Schlesinger Calls U.S. World Role Bleak and He Warns of Soviet Mideast Threat," *Wall Street Journal*, August 17, 1979.

25. James M. Markham, "Kuwait Urges Sharp Oil-Price Rise to Firm Level With No Surcharges," *New York Times*, June 13, 1979.

26. Ulf Lantze, "Welcome and Opening Remarks," in International Energy Agency, *Workshop on Energy Data of Developing Countries* (Paris: Organisation for Economic Cooperation and Development, 1979); David H. Root and Emil D. Attanasi, "World Petroleum Availability," presented to the 37th Annual Technical Conference, Society of Plastics Engineers, New Orleans, May 7-10, 1979.

27. Central Intelligence Agency, "The World Oil Market in the Years Ahead," Washington, D.C., August 1979; Anderson quote from Sidney Fish, "Oil Output Drop Stirs Concern," *Journal of Commerce*, August 8, 1979; "Schlesinger Calls U.S. World Role Bleak."

58 28. Flora Lewis, "European Achievement. Harmony on Oil Problem," *New York Times*, June 23, 1979.

29. "What OPEC Members Charge," *New York Times*, June 29, 1979.

30. Winston Williams, "Sellers Get Premiums in Spot Oil," *New York Times*, July 25, 1979; U.S. Department of Energy, *Energy Supply and Demand in the Midterm: 1985, 1990, and 1995* (Washington, D.C.: April 1979); "Schlesinger Sees $40-a-Barrel Oil," *New York Times*, August 6, 1979.

31. Tax figures from Department of Commerce, *Statistical Abstract of the United States 1978* (Washington, D.C.: 1979).

32. "The Oil Crisis is Real This Time," *Business Week*, July 30, 1979.

33. "Brazil to Spend $5 Billion on Alcohol Fuels Project," *New York Times*, June 9, 1979; for a review of Brazil's alcohol program, see Norman Gall, "Noah's Ark: Energy from Biomass in Brazil," American University Field Staff Reports, Hanover, N.H., 1978.

34. John T. McQuiston, "Gasohol: The Issue is Practicality," *New York Times*, May 19, 1979.

35. Department of Energy, *The Report of the Alcohol Fuels Policy Review* (Washington, D.C.: 1979).

36. *Ibid.*

37. Warren Hoge, "Brazil is High on Alcohol Fuel," *New York Times*, June 14, 1979; Department of Energy, *Alcohol Fuels Policy Review*.

38. For a review of methanol potential, see Department of Energy, *Alcohol Fuels Policy Review*.

39. Details of President Carter's proposal are given in "Fact Sheet on the President's Import Reduction Program," Office of the White House Press Secretary, July 16, 1979; Bumpers quote from Nicholas Wade, "Synfuels in Haste, Repent at Leisure," *Science*, July 13, 1979.

40. For a review of coal conversion technology, see L. E. Swabb, Jr., "Liquid Fuels From Coal: From R&D to an Industry," *Science*, February 10, 1978.

41. Stephen Mulholland, "South Africa's 'Synfuel' Program," *Wall Street Journal*, July 23, 1979.

42. Peter J. Schuyten, "Refinery on Coast Liquifies Coal In Search for an Alternative Fuel," *New York Times*, August 5, 1979. For a review of U.S. developments as of mid-1979, see Richard Myers, "Synthetic Fuels," *Energy Daily*, August 8 and August 20, 1979. 59

43. "Will Oil Sands Ever Pay Off?," *World Business Weekly*, May 14-20, 1979.

44. Dusko Doder, "Tar Sands Hold Promise of Canadian Energy Riches," *Washington Post*, August 13, 1979.

45. Stephen J. Sansweet, "An Oil-Shale Industry Appears to be Nearing But Problems Remain," *Wall Street Journal*, August 16, 1979. For a review of oil shale development, see "Oil from Shale is Still a Distant Hope," *Business Week*, April 23, 1979.

46. Spencer Rich, "As Oil Price Rises, So Does the Cost of Synthetic Crude," *Washington Post*, June 11, 1979, estimates of current costs from "Fact Sheet on President's Program."

47. The capital costs are highly uncertain, but estimates range up to $60 billion for every one million barrels of synthetic fuel. See, for example, Edward Cowan, "Synthetic Fuel Costs Called High," *New York Times*, July 11, 1979; Peter J. Schuyten, "The Synthetic Solution: The Rub is in the Cost," *New York Times*, June 15, 1979; and Morton Kondracke, "Synfuel Madness," *New Republic*, July 21 and July 28, 1979.

48. Brad Knickerbocker, "Environmental Alarm on Synfuels," *Christian Science Monitor*, August 7, 1979.

49. Luther J. Carter, "A Warning on Synfuels, CO_2, and the Weather," *Science*, July 27, 1979.

50. Bloomfield, *The World Automotive Industry*.

51. Department of Energy, "The General Electric/Chrysler Near-Term Electric Test Vehicle (ETV-1)," Information Bulletin No. 404, Washington, D.C., June 1979; Clive Cookson, "Electric Cars Advance in the US," *New Scientist*, July 19, 1979.

52. Cookson, "Electric Cars Advance", Department of Energy, "Electric and Hybrid Vehicle Program: The Second Annual Report to Congress for Fiscal Year 1978," Washington, D.C., January 1979.

53. Cookson, "Electric Cars Advance"; Larry Kramer, "Electrics: Probably Not the Cars of the Future," *Washington Post Magazine*, May 27, 1979.

54. Office of Technology Assessment, *Changes in the Future Use and Characteristics of the Automobile Transportation System, Volume II: Technical Report* (Washington, D.C.: 1979).

55. "Car Companies Drive at Energy Saving Targets," *New Scientist*, July 12, 1979; John M. Geddes, "German Car Makers Set Fuel Cut," *New York Times*, May 1, 1979.

56. Pamela G. Hollie, "G.M.'s Fuel-Saving Car Debuts," *New York Times*, April 4, 1979.

57. Historical trends in fuel efficiency from Oak Ridge National Laboratory, *Transportation Energy Conservation Data Book, Edition 3* (Oak Ridge, Tenn.: 1979); projections of fleet average fuel economy from Richard Shackson, Carnegie-Mellon Institute of Research, private communication, June 14, 1979.

58. For a discussion of energy losses in automobiles, see Jerry Grey, George W. Sutton, and Martin Zlotrick, "Fuel Conservation and Applied Research," *Science*, April 14, 1979, and Joseph T. Kummer, "The Automobile as an Energy Converter," *Technology Review*, February 1975.

59. Department of Transportation findings cited in Office of Technology Assessment, *Changes in Automobile Transportation System*.

60. Valéry, "The Age of Maturity"; Charles B. Camp, "Age of Automotive Dinosaurs Quietly Fading Away Today," *Wall Street Journal*, June 8, 1979.

61. Hofbauer statement from Department of Transportation, *Proceedings of Conference on Basic Research Directions for Advanced Automotive Technology, February 13 and 14, 1979; Volume II* (Washington, D.C.: 1979).

62. Charles E. Dole, "Diesel Cars vs. Pollution Curbs," *Christian Science Monitor*, June 1, 1979.

63. Department of Transportation, *Conference on Basic Research Directions*.

64. CVT's are discussed in Department of Transportation, *Conference on Basic Research Directions*; see also Gerald Leach, *A Low Energy Strategy for the United Kingdom* (London: International Institute for Environment and Development, 1979).

65. Manufacturers' plans for meeting fuel efficiency standards are discussed in "Report on Requests by General Motors and Ford to Reduce Fuel Economy Standards for MY 1981-85 Passenger Automobiles," National Highway Traffic Safety Administration, Washington, D.C., June 1979. Iver Peterson, "Automobile Turbochargers," *New York Times*, July 12, 1979; Ford's fuel injection system discussed in "Petrol Economy," *The Economist*, April 28, 1979.

66. Office of Technology Assessment, *Changes in Automobile Transportation System*.

67. Department of Transportation, *Conference on Basic Research Directions*.

68. Department of Energy, "Electric and Hybrid Vehicle Program Quarterly Report," No. 6, Washington, D.C., April/June 1979.

69. "Dutch Students Get 2,070 MPG," *Washington Post*, June 19, 1979; for a discussion of these car ownership and rental ideas, see C. Kenneth Orski, "Cars of the Future," *Washington Post*, May 22, 1979.

70. Road Research Group, *Energy Problems and Urban and Suburban Transport* (Paris: Organisation for Economic Cooperation and Development, 1977); see also Wilfred Owen, *Transportation, Energy, and Community Design* (London: International Institute for Environment and Development, 1976).

71. Mass transit fuel efficiency figure is authors' estimate based on Oak Ridge National Laboratory, *Transportation Data Book*; Edwin McDowell, "Greyhound: The Year of the Bus," *New York Times*, June 10, 1979.

72. Authors' estimates based on Congressional Budget Office, *Urban Transportation and Energy: The Potential Savings of Different Modes* (Washington, D.C.: Government Printing Office, 1977); average number of passengers per car from Oak Ridge National Laboratory, *Transportation Data Book*; passenger miles per gallon is authors' estimate based on the Oak Ridge data.

73. Owen, *Transportation, Energy, and Community Design*; Owen, *Accessible City*.

74. American Public Transit Association, "Transit Fact Book," Washington, D.C., May 1978; figures on American urban commuter travel from Oak Ridge National Laboratory, *Transportation Data Book*.

75. Road Research Group, *Transport Requirements for Urban Communities: Planning for Personal Travel* (Paris: Organisation for Economic Cooperation and Development, 1977).

76. Wilfred Owen, "Mobility and Accessibility," presented to the Conference on Future Urban Transportation, sponsored by the American Planning Association, Aspen, Col., June 4, 1979.

77. MVMA, *Motor Vehicle Facts and Figures.*

62 78. Organisation for Economic Cooperation and Development, *The Future of European Passenger Transport* (Paris: 1977).

79. World Bank, *Urban Sector Policy Paper* (Washington, D.C.: 1975).

80. Wilfred Owen, *Transportation for Cities* (Washington, D.C.: The Brookings Institution, 1976); Douglas B. Feaver, "Standing Room Only—Metro Absorbs the Shock," *Washington Post*, July 10, 1979.

81. Owen, "Automobiles and Cities."

82. Road Research Group, *Transport Requirements for Urban Communities.*

83. Bicycle Manufacturers of America, private communication, August 29, 1979; Elizabeth Pond, "Will West Germans Use Their Bikes?," *Christian Science Monitor*, November 8, 1978; Mike Hudson and Mike Muller, "Bring Back the Bike—New Moves in Britain," *New Scientist*, November 2, 1978; Paul Kemezis, "Mindful of Oil and Ecology, Dutch are Returning to Bicycles by the Millions," *New York Times*, November 2, 1975.

84. Bailey Morris, "Mania for Mopeds is Nation's Latest European Import," *Christian Science Monitor*, September 23, 1978.

85. Joe Wolfe, Moped Association of America, private communication, July 10, 1979.

86. Oak Ridge National Laboratory, *Transportation Data Book*; Peter Mikelbank, "A Touch of Horsepower for Bicycles," *Washington Post*, April 21, 1977.

87. "U.S. Moped Sales Continue to Soar," news release, Moped Association of America, Washington, D.C., June 12, 1979; Owen, *Transportation, Energy, and Community Design.*

88. Peter Hall, "Urban Transportation: The European Experience," presented to the Conference on Future Urban Transportation, sponsored by the American Planning Association, Aspen, Col., June 4, 1979.

89. Organisation for Economic Cooperation and Development, *Streets for People* (Paris: 1974).

90. Hall, "Urban Transportation."

91. Editors of the Elements, *The Davis Experiment* (Washington, D.C.: Public Resource Center, 1977); Road Research Group, *Transport Requirements for Urban Communities;* Pond, "Will West Germans Use their Bikes?"

92. Peter L. Watson and Edward P. Holland, *Relieving Traffic Congestion: The Singapore Area License Scheme* (Washington, D.C.: World Bank, 1978).

93. Vaclav Smil, "China's Energetics: A System Analysis," in U.S. Congress, Joint Economic Committee, *Chinese Economy Post-Mao,* Committee Print, November 8, 1978.

94. *ILO Labor Force Estimates and Projections, 1950-2000 Second Edition,* Vol. 5. World Summary (Geneva: International Labour Office, 1977).

95. Craig Whitney, "Soviet Sharply Increases Prices of 'Gas' and Coffee," *New York Times,* March 2, 1978; "Gasoline Crisis Mars Vacations for Eastern Europeans," *Washington Post,* August 5, 1979; "The Most Spoiled Communists in World," *U.S. News and World Report,* August 20, 1979.

96. Brazilian information based on visit to the country by one of the authors, July 1979; "Sunday Closing Working in Japan," *Washington Star,* June 6, 1979; Joel Kotkin, "Odd-Even System Eases California's Gasoline Lines," *Washington Post,* June 19, 1979; Judith Cummings, "Two More States Add Odd-Even Gas Sales," *New York Times,* June 28, 1979.

97. Anthony Austin, "Moscow is Raising Price of Luxuries," *New York Times,* July 2, 1979; Sri Lankan information based on visit to the country by one of the authors, August 1979; William Claiborne, "Israel Girds for Fuel Crisis with 'Carless Day'," *Washington Post,* July 10, 1979; "Bulgaria Bans Cars on Certain Days," *Journal of Commerce,* May 23, 1979.

98. Flora Lewis, "Industrial Nations Shaping Accord on Oil-Import Cuts at Tokyo Talks," *New York Times,* June 28, 1979; "French Criticism Irks Carter," *New York Times,* June 27, 1979.

99. "Aug. 1-10 Auto Sales Down 19%," *New York Times,* August 15, 1979.

100. Reginald Stuart, "Chrysler Idles More Workers," *New York Times,* August 9, 1979; Veronique Maurus, "Europe's Faltering Auto Industry: U.S. Eyes Small-Car Market," *Le Monde,* August 3, 1979.

101. Tom Kennedy, "With So Little Native Fuel, Danes Stress Conservation," *Christian Science Monitor*, August 6, 1979; Goran Backstrand and Lars Ingelstam, "Should We Put Limits on Consumption?," *The Futurist*, June 1977.

102. John Neff, American Public Transit Association, private communication, September 4, 1979.

LESTER R. BROWN is President of and a Senior Researcher with Worldwatch Institute. Formerly Administrator of the International Agricultural Development Service of the United States Department of Agriculture, he is the author of several books, including *World Without Borders*, *By Bread Alone*, and *The Twenty-Ninth Day: Accommodating Human Needs and Numbers to the Earth's Resources* (W. W. Norton, April 1978).

CHRISTOPHER FLAVIN is a Researcher with Worldwatch Institute. He is a graduate of Williams College, where he studied Economics and Biology and participated in the Environmental Studies Program.

COLIN NORMAN is a Senior Researcher with Worldwatch Institute. His research deals with the social and political issues connected with the choice and control of technology. Prior to joining Worldwatch, he was the Washington correspondent for *Nature*.