Engineering
and Science

Energy Conservation: Will It Work?

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Whenever anyone talks about the energy "problem" in the United States, we have to wonder whether it isn't a kind of cop-out. As we know, we use 35 percent of the world's energy, but we have only 1/16th of the world's population. That means that on the average we use eight times as much energy per person as the rest of the world. So, even if the world rate of energy consumption (except for the U.S.) were to quadruple in the next 35 years or so, and even if the world population outside the U.S. would only double (which is the best we can hope for), it turns out that the world consumption per capita would still be only about one-fourth of the *present* U.S. consumption per person.

We have been forcefully reminded recently that the already high energy consumption per capita in this country cannot continue to grow at the rate of the 1960's. I'm not talking necessarily about zero energy growth, or about a static society, because I don't understand what that means. I'm talking about a dynamic situation in which we progress from what we knew over a period of 25 years—from the end of the Second World War to the present—to a new era in which we learn how to do with a lower energy growth rate than anything we've been used to.

Remember I said growth *rate.* What I'm concerned with is not the limits to growth but the limits to the rate of growth, which is a different story. It is the central question of the next 25 years. How *are* we going to get through the next 25 years, and especially the next 10? (Some people would say the next *year,* but I would not be that pessimistic.)

What I mean by energy conservation, which is one of the ways to get through this transitional period, is a little bit broader, perhaps, than we're used to, because it includes more than the obvious element of efficiency of the uses to which we put energy. We waste energy in every way possible in this country—in automobiles, in buildings, in industrial processes, even in the growing of food. That will have to come to an end. We will have to learn how to use energy efficiently at its end point.

But there are other effects which are equally interesting, and I call these "saturation" effects. In other words, how many more automobiles can we have after we get up to about 0.8 automobiles per person, which is about one automobile for every person capable of driving a car? If we start getting any more automobiles per person, the automobiles will have to drive themselves around the streets. So there are saturation effects in the sense that we can see a slowdown in the *rate of growth* of certain physical commodities—like the number of square feet of floor area of commercial floor space, the number of residential dwellings, the number of people.

Then there are certain time scales for supply. In order to build new drilling rigs to get more oil, we have to have steel; but in order to have steel we have to have energy. If we have a shortage of energy, we can't have the steel, so we can't build a rig, so we can't drill for the oil, so we can't have more energy. And pretty soon we get ourselves into an impossible situation like the Red Queen in *Through the Looking Glass* who said that we have to run as fast as we possibly can just to stay in the same place.

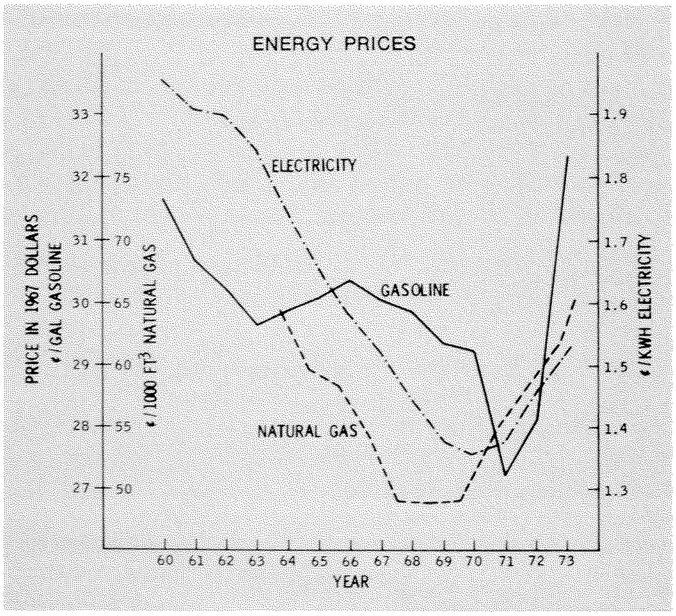
Then my economist friends would have me remind you that there is such a thing as price elasticity, both for demand and supply. By that I mean if the unit price of energy goes up relative to all other things, you're probably going to be a little more careful how you use it. And also if the price of energy goes up in relation to other commodities, those who wish to supply you with energy may be more anxious to do so.

But finally there is an aspect of conservation that has to do with the use of renewable resources rather than non-renewable resources—the use of solar energy, for example, instead of fossil fuels, which are finite. This is a finite planet. Barbara Ward reminded us of that in her book *Spaceship Earth* more than a dozen years ago. And recently I found that on September 6, 1945, President Harry S. Truman sent a special message to the Congress of the United States asking for a National Resource Planning Agency. He didn't get it. But he saw even in 1945 that we would have to plan for these elements of conservation and these elements of supply that I have just mentioned. There was also the famous Percy Commission of June 1952. Its report was largely ignored. It was a very comprehensive piece of work, produced by very able people. Nobody paid any attention.

Interestingly enough, anybody could have predicted what was going to happen. Our domestic production of crude petroleum was rising more and more slowly, our exports were dropping, and our imports were rising by the early 1960's. So anyone could have plotted the curves and predicted what was coming. But apparently we never do anything until a crisis is upon us.

When we look at the last 120 years, we see how total annual energy consumption in the U.S. grew from an equivalent of about 2½ million barrels of oil per day to about 35 million barrels in the early 1970's. Not only did the total energy grow, but there was a vital transformation in the way we *used* energy.

Wood was our primary source of energy in the 1850's. Then coal came along, and its use grew rapidly to equal and surpass wood, then flattened out, and it has stayed flat for about the last 40 years. Oil showed up as a significant source of energy in the 1890's, even though the first strikes were much earlier. It took 20 to 30 years before oil production equaled wood production of energy. Then oil took off, and from 1960 to 1970 we produced more oil in the U.S. than in the preceding 110 years.



Energy prices (shown here in terms of 1967 dollars) actually declined until we had a turnaround in the late 1960's. The latest expectation of electricity prices for residential use is about 4¢ per kilowatt hour (which is 2½¢ in 1967 prices).

Paralleling the growth of oil was the use of natural gas as a clean-burning fuel—its price kept down artificially to stimulate its production (though we're paying the price for that now). Hydropower has had a very interesting history. It has seemed to flatten out at about the equivalent of 1½ million barrels per day, yet its potential is much larger; but because of the environmental consequences of hydropower, we have turned to the other sources.

Another interesting point is that nuclear power in the early 1970's was producing less energy than wood—though it has, of course, now surpassed wood.

In the U.S., the energy consumed *per person* has increased by a factor of about 3½ over the last 120-130 years. In 1850 we consumed about 30 times the human caloric intake per person—about 100 million Btu's per year, or the equivalent of about 2 gallons of oil per day. In 1973 each of us consumed the energy equivalent of about 7 gallons of oil per day.

Can we go on growing like this? We know we cannot, because at the moment we're importing about 7 million barrels of oil per day from outside the continental borders of the United States and Alaska. We're beginning to run down on our supplies of natural gas. And the fossil fuels that have been produced in such enormous quantities over the last 125 years are beginning to run out as far as the United States and its possessions are concerned.

When you look at where energy is coming from, you discover why our imports would continue to grow indefinitely—if we continue to insist on growth in these sectors—and why our dependence on overseas supplies and our imbalance of payments would grow indefinitely. But there are a number of reasons why this will probably not happen. First of all, there's the question of price. If we trace the real price back into the 1960's, for example, we find that this price—the fixed price in 1967 dollars—of electricity, gasoline, and natural gas in the southern California area actually declined (left). In some cases this was because of economies of scale; that is, we were building larger and larger power plants, which were also more and more efficient, so the price of electricity dropped from roughly 2¢ per kilowatt hour to 1.4¢ (in fixed 1967 dollars). But we had a turnaround in the late 1960's, and today the latest expectation of electricity prices for residential use is about 4¢ per kilowatt hour. When we reduce that to 1967 prices, it's still about 2½¢.

Gasoline prices have climbed very rapidly even in 1967 dollars, and natural gas is about to take off—because we're running out of it. Even the Federal Power Commission has recognized that fact. We're running out of it in

California because it can be sold in Texas for $2.00 a thousand cubic feet, but across the state line it can be sold for only 56¢ a thousand cubic feet. So I give you the choice—if you were a businessman, what would you do?

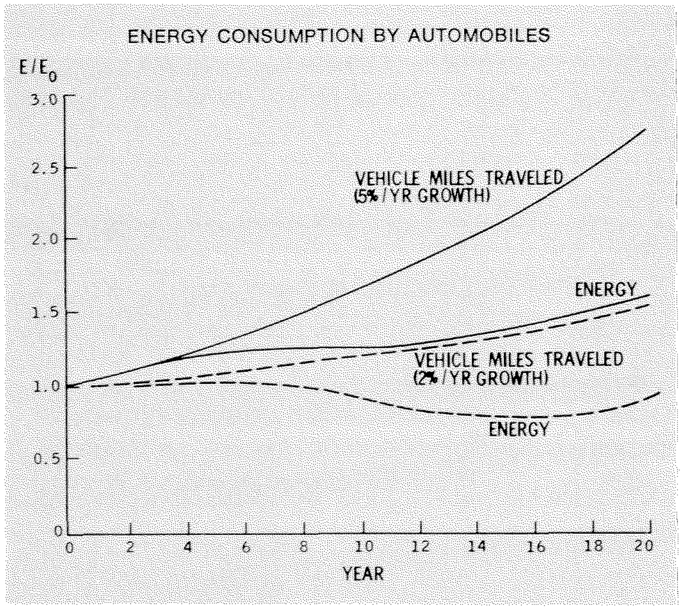
One factor that is going to be important in our lives is that energy is going to be neither cheap nor abundant. When we divide our expenditures for gasoline, electricity, and natural gas by our personal incomes, we can see what fraction of our personal incomes we are spending on energy. During the 1960's it was remarkably constant at about 7 or 8 percent in California, and a little higher in the East where the weather is colder. But *if* the energy growth rate of the 1960's were to continue *and* the present price rises were to continue (largely because of the quadrupling of the oil price by the Oil Producing Exporting Countries, and because of the fact that we're going into deeper and deeper oil wells, the costs of doing business are going up not only in 1975 dollars, but in real terms), then the percentage of our incomes that would be devoted to energy would be on the order of 15 or 20 percent.

You know that's not going to happen. As we realize in our pocketbooks that our expenditures for energy are becoming a larger and larger fraction of our disposable income, we're going to do something about it. The economists predict, for example, that what would happen in the case of electricity would be that the rate of growth in usage would decrease. This is an indication of what's going to be happening over the next 10-15 years. The utilities are already noticing a very slow rate of growth, if any growth at all—and this is making their cash flow problem extremely difficult, so that they are not building as many new plants as had been planned for just a few years ago.

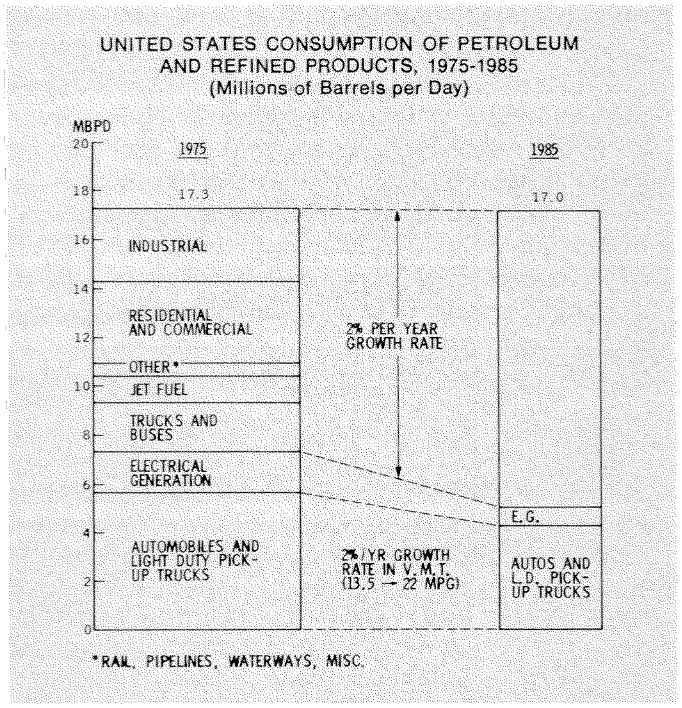
When we come to the question of the efficiency of end use and the question of saturation, the automobile is the chief villain, because it uses about 16 percent of our primary energy. Suppose we started today with the gas guzzlers that get about 13 miles per gallon and began to introduce into the car population efficient cars that got twice that amount—26 mpg. Adopting a very conservative production schedule (we could do much better than this, actually), in the first year we would produce 90 percent gas guzzlers and 10 percent efficient cars. The second year it would be 80-20 percent; the third year, 70-30 percent—until by the tenth year we would no longer produce any more gas guzzlers, and the production lines would roll off only the 26-mpg cars. It would take some time for this to have any effect, but by the tenth year the "mix" would be about 50-50, and the "fleet average" would be 20 mpg, not 13 (the average of 13 and 26).

What would happen to the energy? Suppose that the vehicle miles traveled were to grow at 5 percent a year, which is about what it was doing in southern California over the decade of the 1960's. If we stuck to these 13 mpg cars, in 10 years we'd be using 50 percent more gasoline, in 20 almost 2½ times as much. In the United States we now use 5.6 million barrels of gasoline per day, so that in 10 years we'd be using almost 9 million barrels per day. However, if we introduce these new efficient cars at this very leisurely production schedule, which is easily attainable, at first the energy consumption would rise (because it takes a little while for the rising population of new efficient cars to have an effect), but then the energy would actually decrease, and even after 20 years the energy used by the entire fleet of automobiles, which by that time would have grown by 4 percent per year, would be only about 20 percent greater than it is now.

But suppose that the growth rate is *reduced,* i.e., the vehicle miles traveled grow at only 2 percent per year—which would still leave room for a 1-percent-per-person growth in vehicle miles traveled. (Remember the population is growing at less than 1 percent per year.) Gasoline prices and a change in attitudes would lead us to use our automobiles in a much more intelligent way than we do now. We would be combining trips; we would be using public transit; we would be using more efficient cars. The remarkable thing is that after 10 years we'd be using about 70 percent as much energy for driving around as we do now; and after 15 years we'd be using only half as much (below).

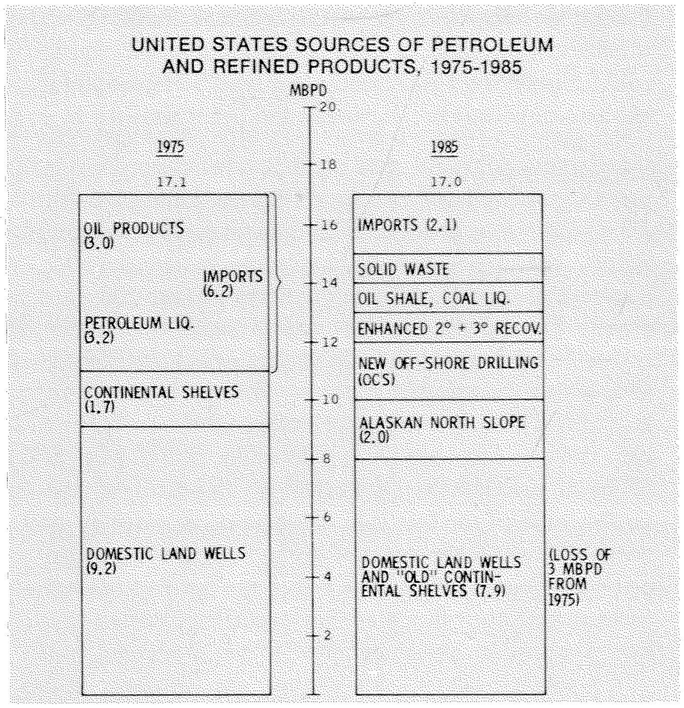


The automobile uses about 16 percent of our primary energy. The top curve here shows how energy consumption would rise with present-day cars and our present growth rate of vehicle miles traveled per year. More efficient cars (second curve) would reduce consumption. Reduced growth rate—using present-day cars (third curve), and more efficient cars (fourth curve)—would reduce it even more.



UNITED STATES CONSUMPTION OF PETROLEUM AND REFINED PRODUCTS, 1975-1985 (Millions of Barrels per Day)

*RAIL, PIPELINES, WATERWAYS, MISC.



UNITED STATES SOURCES OF PETROLEUM AND REFINED PRODUCTS, 1975-1985

We'd save in 10 years about a million and a half barrels of gasoline per day, or more than half a billion barrels a year—which is the equivalent of $5 billion a year—just by doing this one thing with the automobile—namely, either by incentive, by regulation, or by a change in attitude, going from the gas guzzlers to the efficient cars that are technologically available.

If by measures such as this we can keep our total petroleum consumption (above) about the same over the next 10 years (say about 17 million barrels per day), can we match that supply (above, right)? The old wells naturally get pumped out, and we would lose about 3 million barrels per day by 1985, but we could make it up from the Alaskan North Slope (about 2 million barrels per day), new offshore drilling (and I mean environmentally safe offshore drilling), and enhanced secondary-tertiary recovery (meaning injection of steam and other materials to get out more of the oil than we do now), oil, shale, coal, and solid wastes for a total of about 15 million barrels per day. (The most recent expert estimates throw some doubt on the possibility of reaching a goal of 18 million barrels per day by 1985—which only serves to emphasize the need for both conservation and a rational supply policy.)

Our imports would then be down to about 2 million barrels a day, which means we'd be paying oil importers to the U.S. about $7 billion per year instead of $24 billion, and we would have a balance of payments surplus instead of a deficit. So you see we needn't talk about energy self-sufficiency; that's a nonsensical idea. All we have to talk about is a stable position, and that stable position can be achieved by cutting imports from 6 or 7 million barrels a day to 2 or 3 million barrels a day by providing these domestic supplies and combining this with a strong conservation program.

There *are* other ways to do it, but the message is loud and clear: A total national energy policy should seek to freeze the total U.S. consumption of oil over the next 10 years, and should seek to build up our supplies to the point where our imports are no longer a drain on our economy, but, on the contrary, where we have a balance-of-payments surplus. We could even think of being an energy-exporting country in the long run.

The problem of conservation of energy in homes and in buildings is also an urgent one, because of the growing natural-gas shortage, as well as the high price of petroleum imports. We don't have much time either, and unfortunately it takes time to conserve energy.

We asked ourselves the same question that we did for automobiles. Suppose we start building homes, apartments, and commercial buildings that use half as much energy per unit as the current ones. How do we do that? By cutting down on lighting levels in commercial buildings by a factor of at least two, by making sure the air conditioning and the heating systems are not on at the same time, by re-inventing openable windows, by watching the rate of infiltration of air so that we don't take in cold air on cold days and warm it up, or take in hot air on hot days and cool it down any more than we need to, and by glazing, shaping, and shading buildings. There are at least 15 different methods that would, according to the best architectural information we have, reduce energy consumption in commercial buildings and residential buildings by a factor of two if the technologies we know now were put into effect.

Assume that the population of homes and apartments grows at about 2 percent a year, which is its normal rate of growth, but the energy per living unit grows at 3 percent, so that the overall growth is 5 percent. As we introduce buildings and living units which use half as much energy as the current ones, the rate of growth slows down considerably. If we maintain the 2 percent net rate of new construction, but allow the energy per living unit to grow by only 1 percent per year (which is about as fast as the population is growing), then even with no rehabilitation of older homes, the energy use will remain almost constant for 20 years. By updating existing buildings we can reduce the amount of energy we consume by 20 to 30 percent. This is technically feasible. The question is: Is it economically feasible? Are there incentives, are there institutional changes, are there desires on the part of the public to see a national energy policy that has these objectives?

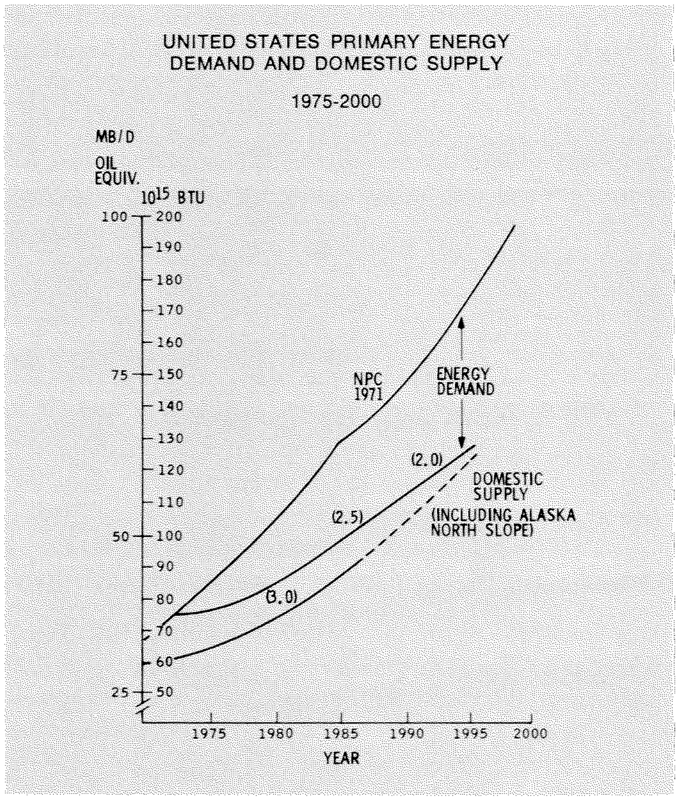
One of the most intriguing of our renewable resources—solar energy—has an element of conservation. Some of the data that have been measured at the Jet Propulsion Laboratory in cooperation with the Southern California Gas Company show incident solar energies of the order of 1 kilowatt per square meter in this climate, or of the order of 4 kilowatt hours per square meter per day. This means that for 100 square meters, or about 1,000 square feet, we're talking about 400 kilowatt hours per day of incident energy, and when we use that solar energy and convert it to heat (not to electricity; this is a thermal conversion system, which is as old as the Egyptians—heating water, using the greenhouse effect, and then converting that water into a system of circulation), we get 60 to 70 percent of the solar energy out.

In southern California, we find that a gas-assisted solar hot water heater would use about 70 percent of the sun's energy and about 30 percent of the gas energy—so the gas company would have a little less of a problem here. That's one of the reasons they're interested in it, and there is now a joint project financed by the National Science Foundation with JPL and the gas company, shifted over to the new Energy Research and Development Administration.

Let's now look at the whole U.S. energy situation over the next 20 years. In 1971 the National Petroleum Council looked at the next 25 years and predicted a 4.2 percent rate of growth in demand up to 1985 and a 3.2 percent rate of growth in demand thereafter up to 1995. The difference between demand and supply would grow indefinitely until our reliance on imports would be intolerable (below).

We are now in a recession, so our energy use has actually dropped. I predict that when it does resume it will do so at a growth rate of roughly 3 percent per year, drop to 2.5 percent per year by 1985, and to 2 percent per year by 1990, if we do all the things I've said.

As to the import situation, the National Petroleum Council predicted that by 1985 we would be importing on the order of 20,000,000 barrels per day from the rest of the world—and by the 1990's it would be a little more

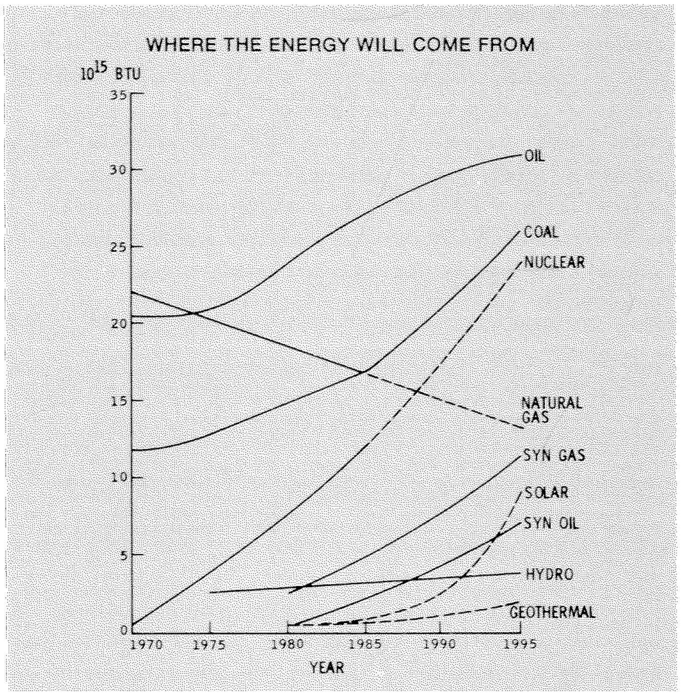


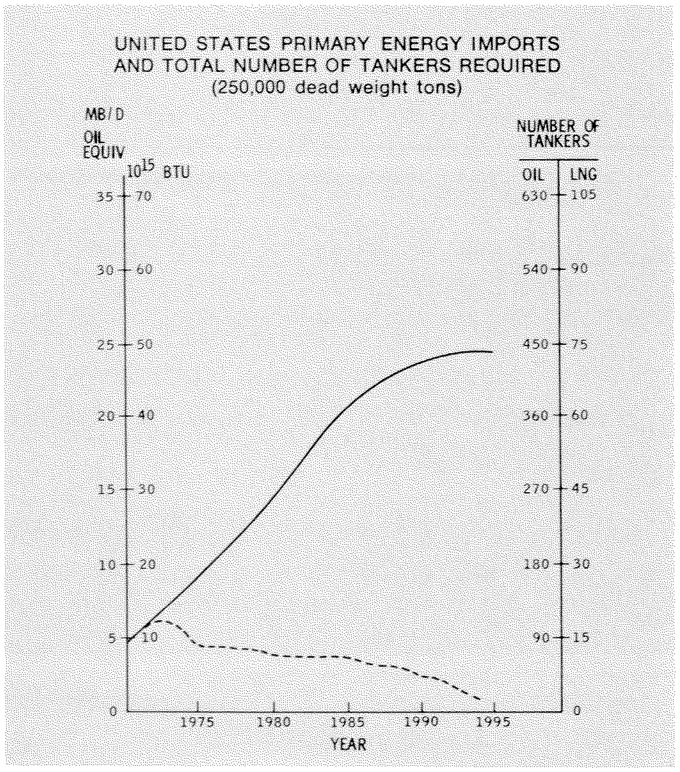
Two projections of energy demand—one made in 1971 by the National Petroleum Council (top curve), and one made by the author (second curve) on the basis of a conservation strategy. The bottom curve is one estimate of our possible growth in domestic energy supply.

than that, as shown in the chart below. However, if the growth rate follows my prediction, which starts up at about 3 percent per year and goes over to 2.5-2 percent per year by 1985, then there would be a steady drop in imports until by 1995 we would have almost a balance of imports and exports of energy.

We have developed a very optimistic scenario that tells where all of this "domestic" energy is going to come from (right). The oil will come from the Alaskan North Slope, plus offshore drilling where it is environmentally acceptable. The coal will involve a complete change in technology. We can no longer mine coal in the old way; we will probably have to do it semi-automatically or fully automatically with hydraulic machinery—robot machinery that goes underground. That's a long story, but we must indeed try to double our coal production. We estimate production of about 200,000 megawatts of nuclear power by 1985 (or about four times what we have now), which would be at that time about 30 percent of our total electrical output. The remainder would be synthetic gas and synthetic oil from coal, and one of my favorite sources—solar energy—as well as geothermal energy and hydroelectric energy.

The message here is that it takes about 15 or 20 years from the time of introduction of any new technology until that technology is contributing as much as 10 percent of the total energy in the country. In the case of nuclear energy it's taking longer than that. Our first successful reactor appeared 25 years ago, and still we are only producing about 11 percent of our electricity with nuclear energy, which is in itself only 3 percent of our total energy.





Two projections of energy imports—one (the upper curve) based on the 1971 National Petroleum Council projection of demand shown in the chart on page 7, the other (lower curve) based on the energy demand with conservation shown on the same chart.

So we have this infernal time scale staring us in the face. Ten or fifteen years seems to be about as fast as we can do anything. Perhaps we can be clever and invent new institutional mechanisms, as we did during the Second World War and in other national emergencies. This is a different world, but I commend to you the fact that this country can do what it wants to do when it makes up its mind to do it. It isn't necessary to go back to washing clothes by hand, and reading books by candlelight, and trying somehow to keep your food from spoiling by using salt and throwing out your refrigerators. What is necessary is to cut down on the rate of growth—not on the use, but on the rate of growth of energy use, and that's a fundamental, philosophical, technological, and institutional distinction. And there are means available for shifting over toward synthetics, clean fuels, toward renewable resources, reducing the rate of growth in our energy consumption, and coming out with a world that will look quite different from the one we have now, but will still be a very good world to live in as far as the United States is concerned. ☐