This material was excerpted from a talk the author gave upon receiving the Annual Award of the Fuels & Petrochemical Div. at the Kansas City Meeting. Currently Science Advisor to the Administrator of the U.S. Energy Research and Development Administration, he has also served as President and Chairman of Houdry Process Corp. and as Vice President of Sun Oil Co. Kirkbride was a recipient of the AIChE Founders Award and is a Past President of the Institute. The statements in this article reflect Mr. Kirkbride's opinions and should not be construed as official statements of ERDA. He is shown on the left here receiving the F&PC Award from Howard Grekel, then Chairman of the division.

Engineering: The Key to Resource Management

Unless this nation unites behind a well-defined, sound, non-partisan energy policy, we may not survive as a democracy.

GL03501

Chalmer G. Kirkbride

The degree of success achieved by any civilization is directly related to the effectiveness with which it uses available energy. A look at human history over the last several thousand years clearly shows that progress is a result of the effective use of energy with tools. In fact, there is almost a straight line relationship between energy consumption and gross national product, with a slope of about 90,000 B.t.u.'s consumed per $ of gross national product (in 1958 dollars). This tells me that we can stop wasting energy and improve the efficiency with which we use energy with a minimum impact on gross national product. But if we reduce our energy consumption by changing our way of life, the gross national product will be reduced correspondingly. This could cause a recession, or even a depression.

During the last 200 years we have seen the development and commercialization of the railroads, the automobile, a modern complex highway system, the tractor, the binder, the combine, the steam ship, the submarine, the airplane, the rocket, the telegraph, the telephone, the radio, television, nuclear fission and fusion, the electric dynamo, the voltaic cell, as well as advances on all fronts of medicine and surgery.

And this is only a partial list. All of these developments were possible because we had a ready supply of almost unlimited mechanical and electrical energy. But, of greatest importance, we had individual freedom and an incentive to invent, develop, and commercialize new machines, new processes, and new compositions of matter for the betterment of mankind. Engineering has indeed been the key to progress and improvements in our standard of living.

"The degree of success achieved by any civilization is directly related to the effectiveness with which it uses available energy."

UNIVERSITY OF UTAH
RESEARCH INSTITUTE
EARTH SCIENCE LAB.

Human, animal, and mechanical energy

In 1850, physical human effort accounted for 23% of our total energy, animal energy for 51%, and mechanical energy for 26%. By 1900, human energy had declined from 23% to 15%, animal energy from 51% to 33%, and mechanical energy had increased from 26% to 52%. By 1950, human energy had further declined from 15% to 4%, animal energy had from 33% to 2%, and mechanical energy had increased from 52% to 94%. Today, only about 2% of our energy derives from humans, almost none of it from animals, and the balance, 98%, is supplied by machines.

During the past 200 years the United States has shifted from an agricultural economy based on human and animal energy to an industrial economy based on mechanical and electrical energy. Even so, we are still capable of feeding ourselves and having excess food to export. In 1800, it required one person on the farm to feed himself plus three other people. Today, one person on the farm feeds himself in addition to 55 others.

The capital investment in the agricultural industry per employee in 1975 was $98,540. Land accounts for $77,620 per employee, so the balance of $20,920 is for power tools and other capital goods used in farming. This, of course, does not include the capital investments to manufacture fertilizer, pesticides, and weed control chemicals. The average capital investment per employee in the manufacturing industries is $55,340. Thus, the agricultural industry's investment per employee, not including land, is 38% of the manufacturing industries' investment per employee, which reflects the large role technology plays in modern agriculture.

Another benefit achieved by our industrial economy is the number of hours per week a man has to put in at work. At the time of World War I, and even up to the early 1920s, it was common for industrial employees to work 12 hr./day, 7 days/week. Today, the average industrial employee works 8 hr./day, 5 days/week and produces far more than his forefathers did.

The increased productivity of the farm worker and the 8 hr. work day of the industrial employee were not the result of legislation, nor were they brought about by organized labor; they were accomplished by technological development that made it possible to substitute mechanical power for human and animal energies and produce far more. Engineering has indeed been the key to resource management.

After 200 years, Mr. and Mrs. America and their children enjoy a way of life that our forefathers were unable to attain. But, in getting to where we are today we have become dependent upon heat energy to supply the necessary forms of mechanical and electrical energy we demand to provide the life we enjoy. Also, we have not been prudent in guaranteeing our supply of this heat energy.

Blissful ignorance shattered

Had it not been for the oil embargo we would still be blissfully ignorant of the energy crisis. Today, our economy is at the mercy of the Organization of Petroleum Exporting Countries (OPEC). In 1975 we had to import about 6 million bbl./day of petroleum, or 38% of the total we consumed during that year. In 1976 it appears that we will import between 7 and 8 million bbl./day, or more than 43% the petroleum we will consume. Petroleum imports in 1975 corresponded to more than $25 billion in negative international balance of payments. These payments for oil imports during 1976 will be more than $30 billion if the price of imported crude is not increased, which is by no means certain. These huge sums must be offset by equal positive balance of

"Had it not been for the oil embargo we would still be blissfully ignorant of the energy crisis."

payments if our international credit is to remain stable. Such positive payments can be achieved by exports or through deposits of gold in banks in the U.S. Unless stability of the dollar is maintained in world markets, it is sure to decline in value. If the situation deteriorates too much, it is conceivable that OPEC might demand payment in gold for the oil they sell to us. That would be unfortunate, if not disastrous.

Recently, Senator Church's Subcommittee on Multinational Corporations asked the Federal Reserve how much gold OPEC has on deposit in banks in the U.S. This information was denied the committee by the chairman of the Federal Reserve Board. Of course it is apparent why this committee wanted the information. If OPEC should build up large gold deposits in international banks in the U.S.—say $20 billion or more—and withdraw them overnight, the dollar might be radically devalued on the world market. In this case, OPEC most certainly would demand payment in gold for the oil they export to us. This would correspond to a substantial price increase in terms of dollars per barrel.

The Energy Research and Development Administration (ERDA) has been given responsibility for, as its name implies, developing alternative sources of power to correct this situation. But, anyone who has had the slightest exposure to this type of R&D work knows that it takes 8 to 10 years to advance such efforts to the point that successful commercialization can begin. Then it usually takes another 10 years to develop the new industry based on the new technology so it can make a significant contribution to the nation's economy. Hence, the ERDA programs will not make any substantial contribution to mitigate the nation's energy crisis before 1980, and the benefits before 1985 will be minor indeed. ERDA should have been created at least 10 years ago. The only way we can have a large impact on the energy shortage by 1985 is to use existing and near-term technologies.

Exotic energy sources

Some people believe that we can solve our energy problems if we would only pursue solar technology more aggressively. Every day, they say, the sun delivers to earth many times the amount of energy the world would need for many centuries to come, and they also point out that sunlight is clean, free, and virtually inexhaustible. That is true, but it

"Solar electricity is one of the three infinite-energy-source technologies ERDA has defined for the next century. But the idea that this technology can make a major contribution before the year 2000 is just not true."

still adds up to a myth. Solar energy cannot supply us today with all the energy we need no matter how aggressively we pursue it.

Solar heating and cooling of homes and buildings is close to being economically viable at present, and ERDA is pushing R&D programs in this field aggressively. Even so, solar heating and cooling has its limitations. In terms of our total energy requirements, it may be able to contribute up to 6% of the nation's total energy needs by the year 2000.

Solar electricity, on the other hand, is a radically different technology and will require far more R&D before it can make any significant contribution. The problems here are efficiency and investment cost. To make solar electric cells economically competitive, we will have to cut their cost and/or increase their efficiency by *several* orders of magnitude. That will take a lot of time, work, and good luck in our R&D. We are very hopeful about this technology, but it is truly a long-term hope. Solar electricity is one of the three nearly infinite-energy-source technologies ERDA has identified for the next century. But the idea that this technology can make a major contribution much before the year 2000 is just not true.

Another source of solar energy is the wind. But, here again, people have been duped into believing the myth that this could provide us with a large part of the energy we need. Nothing could be further from the truth.

Wind once turned windmills throughout this nation to pump water and, in some cases, to generate electricity. In fact, my parents used a windmill to pump water on a claim where I was born in far western Oklahoma. (It was still a territory then.) It is not a question of whether or not the wind is a source of power, but of how large a role it can play in meeting the nation's energy needs.

Suppose the entire nation were dotted with windmills with 500 ft. blades. Those wind wheels would be over 1,000 ft. in diameter, which is about 200 times the diameter my parents used back in Oklahoma between 1905 to 1910. Now, also suppose these windmills would be placed 500 ft. apart in rows 30 miles apart that stretched from the Atlantic to the Pacific. Then suppose the wind blows continuously at 20 mi./hr. These windmills would generate only 20% of the total energy demand today and only 5% of the demand by the year 2000, which, obviously, isn't very much.

Another type of solar energy is biomass conversion, which I am optimistic about for the distant future, but which will make no significant impact on the nation's energy supply much before the year 2000. Process research in this field is being financed by ERDA, but we are a long way from commercialization.

Now let us look at geothermal energy, which some people think will be a significant source of clean energy for the future. We do not know for sure how much this will be, but we can make some reasonably good estimates. It looks like we can count on the equivalent of 300,000 bbl./day of oil by the year 1985. This corresponds to 0.6% of our projected total national energy demand in 1985.

By the year 2000 it looks like we can count on the equivalent of 2.5 million bbl./day of oil, which is 3% of our total projected national energy demand at that time. So here again, it is a myth that geothermal energy will be a major factor in our future energy consumption.

After giving careful consideration to the probable impact of solar and geothermal energy availability in our future, it is apparent that we will have to rely upon far more dependable sources of energy for the remainder of this century.

"For the period beyond 1985, we will be more and more dependent on coal and nuclear energy..."

Oil production

For the period beyond 1985, we will be more and more dependent on coal and nuclear energy and we will have to work at top speed for these energy sources to become a reality by 1985. Then it will be

another 1(
major rol
next 5 to 1
mary sour
domestica
stead of p
tic produc
ing domes
ceilings o
The Fe
a 1976 re
which sho
the 1980 e
about 8.5
1975. The
is 9.0 mill
The cas
ent dome
average p
$5/bbl. b
At a pri
estimated
12.9 milli
dollars/b
today. Th
of domest
price of i
be 3.3 mi
lion bbl./
present p
The eff
of payme
four years
not increa
means ce
of payme
be reduc
some seri
governm
remove a
do the jo
The FI
domestic
which wo
day in 19
correspo
crude oil
bbl./day
way towa
the 1980
It is im
years to
until we
able to g
mediatel
take at le
It seen
great tha
The fede
tion of th
cal mode
ceilings.

Tertiar

The sa

another 10 years before these new sources play a major role in our nation's energy supply. But for the next 5 to 10 years, oil and gas will still be our primary sources of energy. Even so, little is being done domestically to increase oil and gas production. Instead of providing incentives to increase the domestic production of oil and gas, Congress is discouraging domestic production by placing unrealistic price ceilings on these products.

The Federal Energy Administration (FEA) issued a 1976 report titled "National Energy Outlook," which shows that with the price of oil at $8/bbl. the 1980 estimated production of crude oil will be about 8.5 million bbl./day, or about the same as in 1975. The estimated production for 1985 at $8/bbl. is 9.0 million bbl./day.

The case of $8/bbl. crude oil is close to the present domestic situation in the United States at an average price ceiling of $7.66/bbl. This is about $5/bbl. below the average cost of imported crude oil.

At a price of $13 bbl./day for crude oil, the FEA estimated production in 1980 and 1985 at 11.8 and 12.9 million bbl./day, respectively. Thirteen dollars/bbl. is close to the price of imported crude today. Thus, the FEA figures show that if the price of domestic crude were allowed to rise to the present price of imported crude, domestic production would be 3.3 million bbl./day higher in 1980 and 3.9 million bbl./day higher in 1985 than if we maintain the present price ceilings.

The effect of this would be to reduce our balance of payments by about $30 billion during the next four years, assuming the price of imported oil does not increase, which, as I noted earlier, is by no means certain. Also, on the same basis, our balance of payments during the period 1980 to 1985 would be reduced by about $85 billion. This is deserving of some serious consideration. Perhaps the federal government should follow President Ford's advice to remove all price ceilings and let free market forces do the job.

The FEA report also presented estimates of domestic crude oil production for $16/bbl. price, which would amount to 12.7 and 13.7 million bbl./day in 1980 and 1985, respectively. These rates correspond to increases over the case of $8/bbl. crude oil of 4.2 million bbl./day and 4.7 million bbl./day for 1980 and 1985. This could go a long way toward solving the critical energy problem in the 1980 to 1985 time frame.

It is important to understand that it takes several years to develop an oil field, so that if we wait until we are faced with an emergency we will not be able to get the benefit of increased production immediately upon removal of price ceilings; that will take at least 3 to 10 years.

It seems to me that the benefit to the nation is so great that price ceilings should be removed at once. The federal government is discouraging the production of this additional oil that the FEA mathematical model says we could get if we removed the price ceilings.

Tertiary gas production costs more

The same situation exists with respect to the production of natural gas by tertiary methods. There is a deposit of 600 trillion cu. ft. of natural gas in the Rocky Mountain area that cannot be produced by primary production methods because of the very low permeability of this reservoir. There are tertiary methods that might be successful for producing this gas, but the Federal Power Commission has imposed a price ceiling of $0.52/thousand cu. ft. at the well head for new natural gas introduced into interstate commerce. On an equivalent heating value basis this corresponds to $3/bbl. of oil. This situation is even more unreasonable than the price ceiling of $7.66/bbl. for average domestic oil.

The price ceiling on natural gas removes all incentives for producing it. If only a third of the 600 trillion cu. ft. were recovered, it would double the natural gas reserves of the nation.

"Congress is discouraging domestic production [of oil and gas] by placing unrealistic price ceilings on these products."

It would take at least 5 to 10 years to develop this gas field assuming tertiary production is successful. If we wait until there is an acute shortage of natural gas, it will be too late for this gas reserve to help the nation. The FEA report predicted that 25% more natural gas would be produced in 1985 if natural gas price ceilings were removed today.

For a long time we have been living with the idea that energy should be cheap. It is an idea we are reluctant to abandon. But, like it or not, energy is not cheap today, it should not have been cheap in 1960, and it will not be cheap in the future. In fact, the price of imported oil may double in the next few years.

In conclusion

The U.S. must unite behind a sound energy policy. Such a program was developed for President Ford by a group of non-partisan professional people including scientists, engineers, economists, and lawyers. But Congress did not accept it. In my opinion unless this nation unites behind a well-defined, sound, non-partisan energy policy in the near future we may not survive as a democracy.