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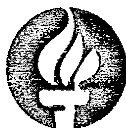

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Energy Resources and Demand

Arlon R. Tussing

Despite the violent surge of fuel prices over the last year, apparently unrelated to long-term changes in demand or in supply costs, the elementary principles of microeconomics, and particularly the shape of the long-term supply function for crude oil, are the keys to projecting future world energy costs and prices.

By the long term, I mean the time span over which the amount and composition of fixed capital can be varied, but one in which radical changes in technology, tastes or the organization of society are precluded—roughly the next 20 years.

During that period, crude oil and natural gas, produced by essentially the same methods as presently, supplemented by synthetic fuel liquids and gases manufactured from other materials and by electricity from nuclear and hydroplants, will continue to dominate the world's supplies of commercial energy. Oil and gas also will be the biggest component of world energy growth, exceeding by several times the incremental contribution of nuclear, hydroelectric and geothermal resources combined.

Energy demand

Historical experience within various countries and cross-sectional comparisons among them both show a nearly linear relationship between real gross product and energy consumption. In other words, it appears that a 4% annual increase in the United States' GNP would require in the future, as it has in the past, a 4% rate of increase in energy consumption. It is not legitimate, however, to assume that this relationship is immutable, and to conclude either that energy consumption is uniquely determined by gross national product or that a significant slowing in the growth of world energy supply would seriously cripple overall economic growth.

Past statistics that show energy consumption in, for example, the United States or Japan rising proportionally with GNP reflect a long period of low and stable or declining real prices for primary fuels. International cross-sectional comparisons of energy consumption and productivity have reflected the general availability of low-price crude oil throughout the world. The industrialized world's technology and product mix have reflected this abundance of cheap energy, and have been prodigal with it.

As we have seen during the last year, a sharp, sudden reduction in the growth of energy supply and a doubling of the prices of primary fuels can indeed seriously affect productivity and income. But we do not really know very much about the responsiveness of energy consumption generally to prices. Our studies of so-called price elasticity refer to individual fuels, and assume that the prices of other fuels remain constant. Nor do we know much about the long-term sensitivity of per worker productivity or per capita real income to the prices of fuel. The likelihood is, however, that the effect of doubling or tripling the real unit costs of primary fuels over a period of, say, ten years would have an almost imperceptible effect upon the total economic welfare of the industrialized world.

In the United States and other industrial economies, the costs of primary fuels (domestic oil, gas or coal fuels at the port of entry) have tended to account for 3 to 4% of national income. If the consumption of energy were completely insensitive to the prices of primary fuels—that is, if there were no opportunities for energy conservation—a tripling of the real costs of primary fuels

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would mean a one-time reduction in real national product and income of 6 to 7%. This is a substantial blow to any economy if the impact of such a cost increase is concentrated in a single year. Spread over a decade, however, its impact would, at worst, be swamped by normal economic growth that ranges in different countries from 50% to 150% per decade. Moreover, the longer period would permit major adjustments in energy use in response to higher prices, so that their total economic impact would be much diminished.

World energy demand and consumption will continue to rise, however, even in the face of rising real prices. Recently, world consumption of crude oil alone has been increasing at a rate comparable to the addition of production from a Prudhoe Bay, Libya or Kuwait every year. Even if price increases should cut the consumption growth rate in half, the potential sources of increased supply to satisfy this demand will be quite different from those upon which the United States has depended in the past.

Energy supply

Let me turn to the world supply function for primary energy in fluid form (liquid, gaseous and electrical) delivered in the markets of the world's great energy-consuming regions: North America, Europe and Japan. Viewed from the standpoint of production and delivery cost, this supply function has three rather distinct segments, which I shall call Class I, Class II, and Class III supply sources. The resource cost thresholds distinguishing the three types are about $2 and $5 per barrel of crude oil (or its BTU equivalent in natural gas or other primary fuels), respectively, delivered in the major industrial nations.

Class I resources are those which might supply any of the industrialized countries at a resource cost of $2 or less per barrel. Class I is dominated by a few unique mineral deposits, the so-called supergiant oil fields, each with 10 billion or more barrels of recoverable reserves. Outside of the Middle East, Alaska's Prudhoe Bay field and the North Sea's Forties field are in this category. In addition to the supergiant oil fields, a substantial proportion of the developed natural gas reserves in the United States are capable of delivering fuel to wholesale customers at a resource cost less than a $2 per barrel crude oil equivalent (about 33¢ per MCF).

The most striking feature of this segment of the world energy supply function is that the overwhelming bulk of the world's Class I resources are in the Persian Gulf basin, and specifically in Saudi Arabia, Iran and Iraq. These countries, together with Kuwait and Abu Dhabi, clearly have among them sufficient proved and probable reserves to supply the entire world, at current rates of consumption and at a production cost of well under $1 per barrel, until at least 1990. *In a fully competitive world market for crude oil,* prices at tidewater everywhere in the world would be Persian Gulf production costs plus transportation, substantially less than $2 per barrel. All sources of primary energy which cost more than $2 per barrel in crude oil equivalent would eventually be driven out of production.

World crude oil prices have never fallen to these levels, nor are they very likely to do so. In the past, the control over the bulk of the world's Class I resources was concentrated in a small handful of international companies, and today it is held by only three Middle Eastern governments. The interest of both sets of parties—the companies and the producer governments—has been in stabilizing or increasing the world price of crude oil and has led them, through a variety of overtly or indirectly collusive mechanisms, to avoid the competition which would force prices down to the supply cost of Class I crude oil. This producer interest in high world prices was abetted until recently by energy policies in almost all the major consuming countries, aimed either at protecting a higher cost coal industry to preserve employment or at protecting a higher cost domestic oil industry in the name of national security.

The price of Persian Gulf crude oil has always been determined, not by its own cost but by the cost of some higher price alternative. At various times, the price basis for world crude oil has been the price of crude oil from the U.S. Gulf Coast or Venezuela and the cost of European coal.

The same principle applies today; the price of Class I crude oil will be determined by the cost of more expensive energy sources. In the short term, however, there is *no* practical alternative to Persian Gulf crude to meet the increases in either U.S. or world consumption. A crude oil price of $10 or more per barrel is in this sense a monopoly price, a price determined by current scarcity, rather than long-term cost. That price reflects the cost of doing without oil at all in the interval before the lowest cost alternative sources that are available can actually be put on stream.

Class II supply sources are those which can deliver primary fluid fuels to the major industrial countries at costs between $2 and $5 per barrel. They include most of the proved and potential reserves of conventional crude oil in the United States, Canada, the Caribbean, Africa, Indonesia, and many other countries.

These resources are far more widely distributed than the lowest cost supergiant oil fields, but their known

and proved volumes of oil are substantially less than those of Class I. Class II petroleum deposits are consequently much more intensively exploited than Class I resources: depletion rates of Class II oil and gas in the United States range from 5 to 16% per year, in contrast to a typical Persian Gulf figure of about 2%.

Thanks to an abundance of Class II resources, the United States was nearly self-sufficient in energy until about two years ago. But because of their relative scarcity and their intensity of exploitation, these sources must constantly be renewed by fresh discoveries. Exploration and increasingly intensive development of known reserves of Class II resources (particularly of natural gas) have continued to add to our fuels inventory, but they have not kept up with the growth of consumption. The United States in 1971 joined Europe and Japan in having to rely upon the supergiant fields of the Middle East for its incremental supply of energy, with the disastrous consequences we have seen in the past few months.

Smaller oil reservoirs are far more numerous and widely distributed than huge ones, but most of the recoverable oil found in any producing province seems to occur in its largest reservoirs. The same seems true of each country and the world as a whole: one-fourth of U.S. proved reserves are in the Prudhoe Bay field, and half of the world's proved reserves of crude oil are attributable to less than a dozen supergiant fields. As a consequence, proved reserves of Class II in the world are now far smaller than those of Class I, and the future additions to Class II reserves are more uncertain. Recent exploratory history either in the United States or worldwide has not been encouraging about radically increasing the rate of growth either of Class II reserves or of Class I reserves outside the Persian Gulf. It appears, therefore, that incremental energy supplies, both for the United States and for the world, will have to come from Class I resources in the Persian Gulf, or from Class III resources.

Class III supply sources are those whose output is available over the long term in the industrialized countries for prices equivalent to crude oil at more than $5 per barrel. The variety of Class III resources is very large, and several of them are potentially almost unlimited in extent.

One Class III resource is the oil that is ordinarily left in the ground when Class I and II resources are exploited. Because of the tendency of the largest fields to contain the greater part of the total oil-in-place, most of the conventional crude oil, conventionally extracted, either in the U.S. or worldwide, can be expected to have a resource cost of less than $5 per barrel. But only 30% of the known oil-in-place is typically recovered; at progressively higher costs for so-called secondary and tertiary recovery, greater proportions of the total oil can be recovered. A doubling of recovery rates, which is believed to be technically feasible, would more than double U.S. proved reserves figures, extending their so-called life index (the reserve-to-production ratio) by more than 10 years, but much of this oil would be available only at a cost greater than $5.

Natural gas produced from supergiant oil fields—or from their equivalent in dry gas fields in the Middle East, Africa, the Caribbean, the USSR and the North American Arctic—is also a huge potential Class III resource. This gas can be produced in the field (or recovered from oil wells rather than flared, as at present) at exceedingly low cost; that is, for only a few cents per million BTU. Such gas, if it were found close to consuming markets, would be regarded as a Class I resource. But in contrast to oil, which can be shipped almost anywhere in the world for $1 per barrel or less, the cost of transporting gas long distances by pipeline, or by tanker in the form of LNG or methanol, will place the delivered price from most sources in the major markets of the world on a par with that of $5 to $10 oil.

Even more extensive than conventional oil and gas resources are the deposits of other hydrocarbons. At least three such deposits are known to exist in the Western Hemisphere, each of whose proved reserves exceed those of the whole world in conventional oil and gas. The Orinoco tar belt, the Rocky Mountain oil shales and the Athabasca tar sands are all capable of being produced at costs somewhere in the $5 to $10 range. Similar resources may occur elsewhere, but because there has heretofore been no incentive to explore for them, their abundance and distribution is almost unknown.

Synthetic crude oil, synthetic natural gas and electricity can also be produced from coal with energy costs in the $5 to $10 range. The resource cost of electrical power from light water nuclear reactors is in the same range. In summary, the potential supplies of energy from Class III resources, like those of Class I but probably unlike those of Class II, are in principle capable of filling the world's foreseeable incremental energy demand.

Not all of these Class III energy sources are practically unlimited, and several are not yet proved in commercial production. Most important, however, they all involve high fixed capital outlays, and very long lead times compared to Class I and Class II energy sources. These new supplies, while essentially unlimited as a group, will not come on stream overnight. In each case,

moreover, future cost estimates must be qualified with great uncertainty.

Where we stand

To recapitulate, there are three segments of the world supply function for primary energy; either the lowest or highest cost of the three segments could clearly sustain the growth of world energy consumption for two decades; it is improbable that the medium-cost segment can do so. Until two years ago the United States could still depend upon its Class II resources for growth, and the incremental costs for these sources influenced the price of Class I energy both at home and abroad. Under these circumstances there was little economic incentive or strategic justification for developing synthetic oil or gas, for building pipelines to bring gas from the Arctic, or for hauling LNG across the oceans.

Today, it appears that some or all of these projects begin to make sense. Not in terms of resource costs—the world as a whole would be better off economically and environmentally using 10¢ per barrel Arabian crude oil, whatever its price, than strip-mining coal or tar sands and manufacturing oil or gas at $5 per barrel and more. But the supergiant oil deposits are too concentrated geographically and politically, for the industrialized countries to be able to accept long-term dependence upon the Persian Gulf for the growth of their energy supplies. Despite the wastefulness of Class III energy sources (and they are wasteful—of labor, capital and environmental quality), the energy consuming nations must build Class III energy supply capabilities.

Because of the high fixed capital requirements of synthetic fuels, Arctic gas transportation, gas liquefaction and nuclear power, Class III energy sources will, if they are constructed at all, be designed to serve as our base load supplies, and the cheaper sources, including Middle Eastern imports, will, ironically and perversely, be treated as interruptible or peaking supplies—as a surge tank or balance wheel. Unless a new exploration boom or new technology (such as a "direct finding tool"—the ability to detect oil in the ground and estimate its volume without drilling) reverses the decline in conventional oil and gas production in other than the supergiant fields of the Middle East, or unless a cheap in situ process is rapidly developed to extract oil from shale or tar sands, the lower part of the Class III cost range will set the prices of all energy, and determine the windfalls—the economic rents—that will be captured by those such as the Arabs, Iranians, Norwegians and the Alaskans, who control substantial Class I resources.

If vast discoveries of Class I resources outside the Persian Gulf were to decentralize the control of the world's low-cost energy supplies, neither two nations (Saudi Arabia and Iran) nor a handful of multinational oil companies would any longer be able to determine, unilaterally or in concert, the rate of growth of world oil supply, and thereby to set world oil prices. The result might also be the same if Occidental Petroleum's claims of a low-cost in situ technique for shale oil recovery are sustained. A direct finding tool might open up a whole new discovery cycle for Class I and Class II oil and gas resources. Perhaps, as the *Economist* has forecast, we will see a dreadful glut of oil in the world in only a few years.

These are plausible events, but the world would not be wise to count on them. We must plan as if price and volume of *reliable* supplies will both be determined by marginal production in the lower part of the Class III segment of the aggregate supply function.

The prices of oil and other forms of energy, like those of commodities generally, are determined at the margin; that is, the prices of energy in each market will reflect the highest cost component of supply. Because a large proportion of total supply will be produced at a cost substantially lower than the prevailing price, the energy industries will continue to generate vast differential rents for those who control resources that can be developed at low cost. Whether the world price of oil or its equivalent in other hydrocarbons is $2 or $20 and whether the United States' domestic oil price is higher or lower than the world price, there will still be gigantic reservoirs that can be produced at $1, or 40¢, or even 8¢ per barrel.

This unearned bounty—the difference between cost and price on an ever-growing volume of production—will total tens of billions of dollars each year. Its division and disposition will be a continuing and growing source of turmoil in each producing country (including our own) and among nations.

Alternatives pose dangers

There are two related dangers in pushing ahead with coal and oil shale conversion, enhanced recovery from known fields at high cost, Arctic gas transportation and Eastern Hemisphere LNG. The first danger is that after tens or hundreds of billions of dollars have been sunk into these high-cost alternatives, the price of Persian Gulf oil would almost certainly fall to whatever level would be necessary to keep or recapture its world markets. Without some kind of price, tariff or quota protection for the new high-cost domestic energy sources, they would become economic disasters.

The ability of major consuming countries to produce

their own incremental energy supplies from Class III sources will reduce world oil prices to a level no higher than the cost of energy from those alternatives. The assurance that some countries like the United States will undertake the costly effort to develop its Class III resources will give others like France a free ride. Without the huge capital outlays necessary to produce Class III energy, these free riders will reap the benefits in the form of oil from the Middle East at a price at least as low as the cost of fuels based upon Class III resources. The free riders will, moreover, be in a superior competitive position if world crude oil prices should again fall *below* U.S. domestic prices.

The domestic tensions that will result from our own reliance upon and protection of Class III energy sources at $6 or $7 per barrel or more should not be underestimated, particularly in the face of the huge differential rents which will be reaped by owners of domestic Class I and Class II resources. If world prices fall, heavy and continuing pressure will be inevitable from consumer interests to take advantage of cheaper imports, to the disadvantage of high-cost domestic producers.

The opposite is overcapitalization and overprotection of high-cost energy sources. If the United States (or other consuming nations) encourages the development of "any and all" Class III resources by pricing policies, tax or direct subsidies, or governmental enterprise in order to get out of the present crisis as quickly as possible, vast amounts of capital will certainly be invested in projects which are not in any sense economic over the long term. The present policy of allowing the prices of "new" and "released" oil and oil from stripper wells to reach $10 or more per barrel signals private enterprise that such prices are viable and rational in the long term—which they are not. The massive investments that will be made in Class III resources in response to these signals will create a powerful vested interest in perpetuating high energy prices.

The path between these two dangers—lack of protection and overprotection—is a faint one across a difficult terrain, particularly for those of us who lean toward market solutions to economic problems. Unfortunately, there is no tolerable free market answer to the energy dilemma, because the world market for primary energy lacks stable conditions of equilibrium. Tolerable security of energy supply, an assurance that primary energy prices will be reasonably predictable, and assurance indeed that they will be nearer to $5 than $15 per barrel, require some combination of tax preferences, price controls or price supports, subsidies and restrictions upon imports or exports.

For any such program to be acceptable to the American people, it is essential that economic rents—unearned profits—from the production of low-cost resources be severely controlled. People will not stand for an energy policy that supports fuel prices at Class III levels while the owners or operators of Class I and Class II resources reap billions or tens of billions of dollars annually in economic rents.

One approach to limiting excess profits is the creation of a permanent two-tier or multi-price system for energy, in which there is one price for low-cost fuels and another for high-cost fuels. Such a system already exists under FPC regulation of natural gas, and has recently been created by the Cost of Living Council for crude oil and petroleum products. Arbitrary lines drawn between classes of producers or production facilities can never demarcate clearly between the components of energy supply which are price-responsive and those which are unresponsive, so that every multiprice system permits some unearned profits and at the same time creates some disincentive.

The imprecision in terms of incentives of a system distinguising "new" oil or gas from "old," synthetic hydrocarbons from natural hydrocarbons or stripper wells from flowing wells might be tolerable, but it also creates substantial inequities among classes of consumers, and encourages consumers who have access to the low-priced component of supply to use it wastefully. The U.S. market for natural gas, which is properly our highest price premium fuel, is the best example of the mischief worked by a multiprice system resting upon cost-based regulation. Despite the growing shortage of gas for household use, more than half the total supply is now being burned under industrial boilers, mostly in the producing states.

The price we pay

There is a strong case for some kind of subsidy for production of high-cost domestic fuels in the form of either direct outlays or tax preferences. By lowering the consumer prices of the highest cost component of supply, such subsidies would reduce the spectacular economic rents that will be reaped by those who control low-cost energy sources. Consumers would not, for example, have to pay the equivalent of $7 per barrel for the perhaps 80% of domestic supply which could be provided at $4 or less, thereby vastly enriching the producers of the latter.

Because there is no long-term equilibrium price for primary energy in the United States (unless the nation cuts itself off from both imports and exports of energy),

it is futile to talk about moving toward establishing or restoring a free market in energy or to speculate about a long-term market clearing price.

The price that prevails for energy 5 or 10 years from now will be directly determined by "interferences" with the market mechanism. That price will inevitably be essentially a political decision, depending on the judgment of policy-makers regarding the range of technological options, the risks of import dependence, the amount of subsidy that taxpayers will tolerate, and the degree of price protection consumers will tolerate. Implicitly or explicitly, the United States will have to begin now to set a price policy; consumer prices which turn out to be too low will be offset by subsidies and export controls or by a more costly remedy: permanent rationing. Prices which turn out to be too high will inevitably be protected by import restrictions and production controls. These policies will generate very conspicuous economic rents and will exacerbate domestic political conflict, leading possibly to nationalization of at least a part of the energy industry.

It is not likely that *reliable* energy supply can again be obtained at prices less than $5 per barrel, crude oil equivalent. Because supply will still include important Class I and Class II components, however, the average *cost* of energy to the economy as a whole will be considerably less than its price. This cost can be minimized by a policy which will encourage increased production from our substantial Class I and II resources, particularly offshore and in Alaska. The two most important elements of this policy are probably more rapid leasing on the outer Continental Shelf and sharp increases in the field prices of natural gas, which under FPC regulation are now equivalent, on the average, to crude oil prices of about $2 per barrel, or to fuel oil at 3½¢ per gallon.

If these steps are taken, I believe that we might be able to set a long-term target price in the lower end of the Class III range—perhaps about $6 per barrel in 1974 dollars. This is almost twice the level of one year ago. But it is still substantially less than average domestic crude oil prices today, and about half of the current "free market" price. However, my $6 estimate is, as I have stated, not a judgment about supply-demand equilibrium, but about a political equilibrium. ▪