CONF-921147--1

ANL/CP--75651

DE93 004234

THE CONTRIBUTION OF THE DOE'S R&D BUDGET IN NATURAL GAS TO ENERGY PRICE SECURITY

by

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for presentation at the
International Association for Energy Economics
Thirteenth Annual North American Conference

November 18-20
Chicago, Illinois

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Work supported by the U.S. Department of Energy, Office of Policy, Planning and Analysis, under contract W-31-109-Eng-38.

Energy security is one of the major goals of national energy policy. The R&D proposal of the natural gas industry asserts that several of the proposed investments would contribute to energy security. This section is a conceptual and preliminary empirical analysis of the potential of natural gas R&D to contribute to energy security.

The National Energy Strategy recognizes that the U.S. economy is vulnerable to world oil price changes. Oil vulnerability has been defined in previous years to reflect the share of oil imported, or, the share of oil imported from OPEC. Supply restrictions from the Middle East have been the precipitating cause of past oil price increases and perhaps the most likely cause of future price increases. Supply restrictions affect the world oil price, which in turn affect the macro performance of the U.S. economy. Energy security refers to the vulnerability of the economy to the effects of energy price shocks. The DOE is currently defining energy security as "Energy security is measured by the expected economic damage the Nation will suffer from energy supply disruptions over a given period of time". This measure of energy security correctly reflects the probability of an oil price shock, its intensity and its expected duration.

This analysis considers only one component of energy security, namely the volatility of energy prices. R&D investments that reduce energy price volatility also contribute to energy security. Reducing energy price volatility would enhance energy security, although other policy targets could also achieve this result. The objective of energy price stability includes a stable price of natural gas and electricity, even though each is produced for the most part domestically. Price increases in electricity are not only influenced by fuel prices, but were affected by rising capital costs, particularly of nuclear power plants. The goal of energy stability refers broadly to the total costs of energy services and not merely to a specific fuel.

Future Price Risks

The insurance provided by natural gas R&D against oil price changes depends on the nature of the price change throughout the NES planning period through the year 2030. Figure 1 depicts some possible future world oil price trends. The base case is a gradual and steady long term increase in the world oil price of, say, 3 percent per year. This trend is not a forecast, but rather a hypothetical base case from which energy price risks can be defined.

One possible deviation from the base case is a long run gradual rising price. In Fig. 1 such a trend is depicted as a 4 percent annual increase in world oil prices, instead of the 3 percent annual increase in the base case. Gradually rising prices do not necessarily reflect market imperfections. Long run competitive costs of producing oil, or energy in general, may rise over time. Private markets make economically efficient adjustments to gradually increasing input prices, including the price of oil. The DOE R&D strategy need not be designed to mitigate the consequences of such a price increase. Alternatively stated,

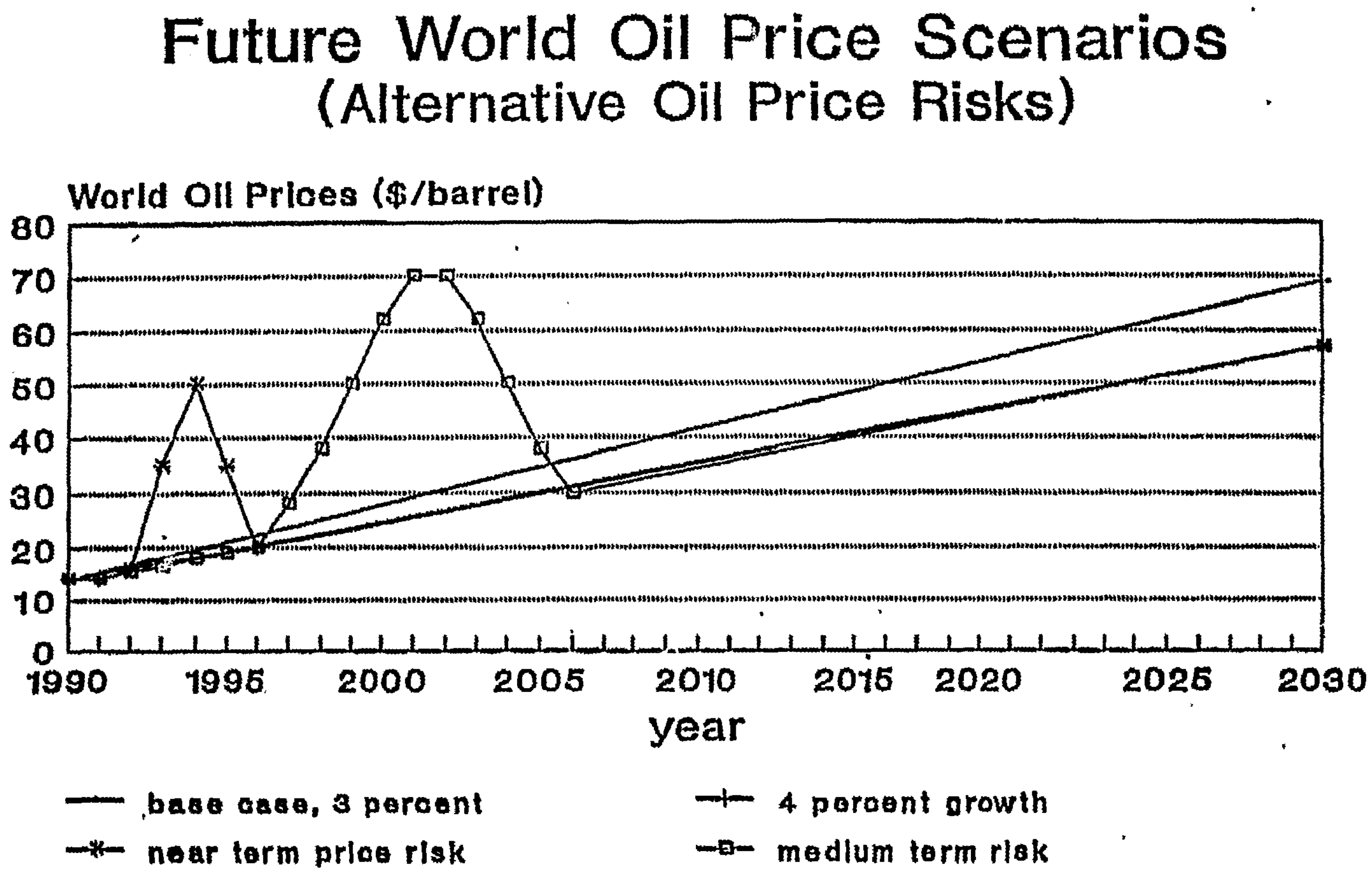

Future World Oil Price Scenarios
(Alternative Oil Price Risks)
World Oil Prices ($/barrel)
80
70
60
50
40
30
20
10
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
year
base case, 3 percent
4 percent growth
near term price risk
medium term risk

FIGURE 1

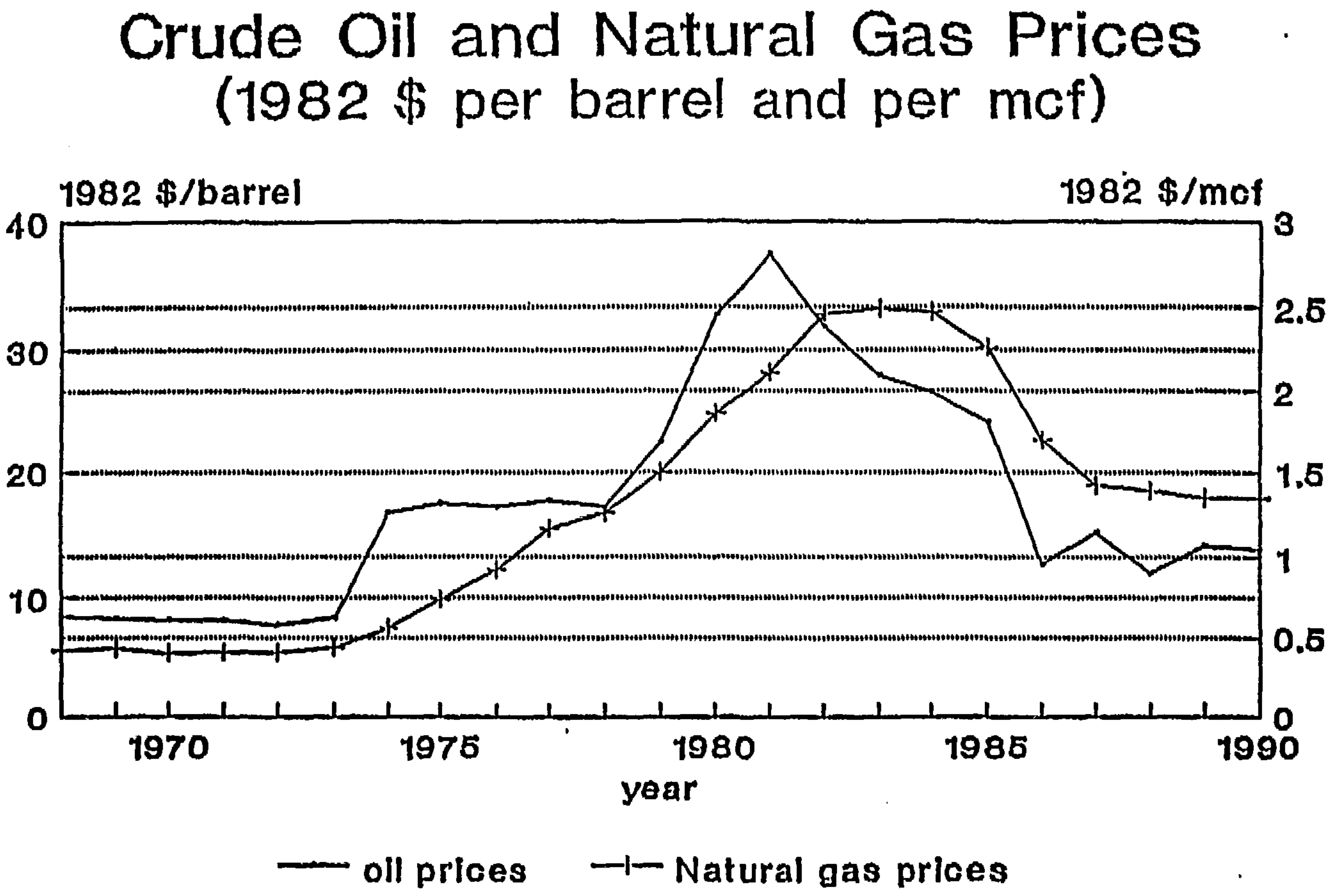
decline in oil prices. This scenario is reflected by an assumed increase in oil prices to $65 by the year 2001, followed by a return to the base case. The SPR is limited in offsetting such price movements and is not designed for this purpose. Energy R&D can be designed to reduce the economic impact of such price movements under the goal of promoting energy security. Some energy R&D investments will not insure against short-term price increases but will provide protection against medium term price increases. Defining the nature of energy price change that is the target of energy R&D therefore becomes important.Private markets do not provide adequate protection against the consequences of short run (2 to 3 year) oil price increases and more medium term (5 to 8) year price increases. DOE R&D strategy, for energy security purposes, can be targeted against such contingencies.

The natural gas R&D that provides insurance against long term oil price increases includes both gas supply research and the development of gas utilization technologies that substitute for oil. This R&D does not require a short term payoff, nor does it require economic feasibility at current prices. For instance, gas supply R&D that contributed to an increase in gas reserves at $4/mcf may not be appealing to the gas industry, but would provide protection against long term oil price increases. With an increase in oil prices, several sectors would substitute gas for oil, putting upward pressure on gas prices. The availability of $4 gas would limit the overall energy price increase.

An Historical Perspective

The historical record of oil and gas prices provides an intuitive understanding of the energy price stability that would have been obtained by switching from oil to gas. As seen in Figure 2 historical oil and gas prices experienced similar trends. The average price of natural gas delivered to consumers was just over $0.55 (per mcf) from the middle 1960's through 1971. This price increased continuously through the 1970's and early 1980's, reaching a peak of $4.67 in 1984. Prices then declined continuously throughout the 1980's (Natural Gas Annual). The refiner acquisition cost of crude oil increased from about $4.00 per barrel in 1973 to a peak of $35 dollars in 1981 and then fell continuously to about $14 per barrel by the end of the 1980's. The timing of the historical oil and gas price changes match closely, with the increases occurring from 1973 through the early 1980's, followed by price declines. The magnitude of the price changes also matches reasonably well, with the price increases increasing by a factor of about 8 and then decreasing by a factor of about 2.

One implication of these historical trends is that the price risk of oil and gas has been of similar magnitude. A consumer of natural gas would have been subject to about the same price risks as a consumer of oil. Secondly, diversifying from oil to gas, at least historically, would not have significantly reduced overall energy price volatility. These results are sensitive to the unit of measurement of the variables, which is $/barrel and $/mcf of gas. The conclusion follows from the similar magnitude of the historical price movements and their temporal correspondence. That is, using gas instead of oil would have left the consumer vulnerable to price movements of similar size and occurring at a similar



Source: Annual Energy Review 1990

FIGURE 2

time. The purpose of this figure is to convey that simply substituting gas for oil does not ensure energy price stability.

One question is whether substitution into gas would reduce the vulnerability of the U.S. economy to future oil price movements. Another consideration is whether gas R&D projects could be selected or designed so as to reduce the variability of gas prices and the covariability of gas prices with oil prices. The issue of covariability between oil and gas prices is not with short term price movements, such as quarterly or monthly, but with longer term price changes. For instance, could gas prices remain stable in the event of an oil price shock over a short term (2 to 3 year) period, or a multi year price increase as depicted in Figure 2?

The historical correlation between oil and natural gas prices is explained in terms of causation. Oil prices are determined on a world market. In contrast, natural gas prices in the U.S. are determined by domestic supply and demand. A change in the world oil price affects the domestic demand for gas and hence its price. For instance, an increase in world oil prices results in the substitution of gas for oil, primarily in the industrial and electric utility sectors. This increase in the demand for gas causes its price to rise. The extent of the increase in the price of gas depends on its price elasticity of supply. In the short run, the link between gas prices and oil prices depends on the excess capacity to produce gas at current prices. Over a several year period of rising oil prices, the link between gas and oil prices depends on the marginal cost of discovering and producing gas. These costs are affected by Government R&D. As noted by Hay (1990, p. 19), oil prices are generally considered a predominant variable in influencing the supply and demand for gas.

A Price Volatility Model

Energy price volatility resulting from natural gas R&D can be estimated from a simple energy price model. Because the analysis is concerned only with oil and gas prices, the appropriate energy price is a weighted sum of these two fuel prices. The price of energy can be expressed in equation form as

(1) Price of Energy = w_1Price of Oil + w_2Price of Gas

where $w_1 + w_2 = 1$ and the weights (w_1 and w_2) are the share of each fuel in total energy (oil plus gas) consumption. The price and quantity of the fuels are measured in common units, such as Btu. Using 1990 data for the aggregate U. S. economy, oil accounted for 63.4 percent of the total consumption of the two fuels. Equation (2) is estimated as

(1') \$2.39 = .634 x \$3.05 + .366 x \$1.24, which asserts that the average price of energy (oil plus gas) was \$2.17 per million Btu at the wholesale level.[1]

Fuel prices are viewed as a random variable with a probability distribution, where the variance is a measure of fuel price volatility. Energy price volatility can be measured as the variance of the price of energy. A statistical property of random variables is that the variance of the sum of two random variables is the sum of their variances plus twice their covariance. The variability of energy prices can therefore be expressed as the variance of the sum of the variances of the oil and gas prices plus twice their covariance. Using σ^2 as a statistical variance, the equation for energy price variability is written as

(2) σ^2 (Price of Energy) = $w_1^2\sigma^2$ (Price of Oil) + $w_2^2\sigma^2$ (Price of Gas) + $2w_1w_2\sigma_{12}$

where the Btu share of oil and gas are denoted by w_1 and w_2. In this model, energy price volatility is obtained by reducing the variance of the price of energy. The algebraic property of this equation indicates that the variability of the price of energy can be reduced by: (1) changing the share of gas relative to oil, (2) reducing the variability of the price of gas (or oil), and (3) reducing the covariability between oil and gas prices.

The variance of the price of energy is estimated from historical data based on the variance of the price of each fuel, their covariance and the Btu share of each fuel. In 1990, the oil share of aggregate energy consumption was .634 and the gas share was .366. Fuel price data are in annual 1982 dollars in millions of Btu and the sample period is from 1967 - 1990. The variances of oil and gas prices are estimated as \$2.299 and \$0.506 respectively. The larger variance of oil prices reflects in part a larger sample mean, which is \$3.05/mmBtu compared with \$1.24/mmBtu for natural gas. The estimated covariance between these fuel prices is .9017, which reflects a correlation coefficient of 0.84. The positive covariance indicates that oil and gas prices moved together over the sample period. Substituting these numbers into equation (2) yields the equation

(2') \$1.410 = .9241 + .0678 + .4185,

where the terms measure the weight of historical oil price variability, gas price variability and the covariance between these prices. Unfortunately, the variance does not have a useful intuitive interpretation - it is the expected squared deviation about the mean - but it can be used for comparative purposes.

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[1] All data were taken from, Energy Information Administration, Annual Energy Review 1989, Washington DC, DOE/EIA-0384(89), May, 1990. The input data and their corresponding page numbers are: refinery acquisition cost, \$14.22/barrel, p. 151; nominal wellhead price of gas, \$1.71/mcf, p. 173; natural gas consumption, 18.95 trillion cubic feet, p. 161; petroleum products supplied, 17.24 million barrels per day, p. 115; oil has 5.8 million Btu/barrel p. 284; natural gas has 1035 Btu/cubic foot.

The above equation indicates that diversifying from oil to gas would have reduced energy price instability. The variance of the gas term is less than one-tenth the variance of the oil term. A small reduction in the variance of the price of energy indicates a minor improvement in energy price stability and similarly a larger reduction in this variance reflects more of an improvement. Historically, oil price variations have made a larger contribution to aggregate energy price variability than have gas prices.

Natural gas prices have contributed to energy price changes,in part by being volatile, but primarily by being correlated with oil price increases. The weight of the covariance term (.4185) indicates that the strong positive correlation between oil and gas prices has historically contributed to energy price volatility. In contrast, the variance term of gas prices (.0678) makes a much smaller contribution to energy price instability. An energy security hypothesis suggested by this model is that volatile oil prices affect the transportation and industrial sectors and affect natural gas prices. These prices in turn affect the commercial, residential and electric utility sectors. Oil price risks have a direct but small affect on these sectors, but their main affect is via gas prices.

Equation (2) is used to indicate the effect of R&D investments in natural gas on price volatility. An R&D investment enhances energy price stability by reducing the overall variance of energy prices. Algebraically, this variance is reduced by decreasing any of the terms on the right hand side of the equation. The results of several illustrations are presented in Table 1. The first illustration is simply the base case estimated with historical data. In the second illustration, we assume that a gas R&D investment leads to the substitution of natural gas for oil. In this case of increased diversification, the share of gas increases so that gas and oil have equal shares in total aggregate energy consumption. In the above equation, w_1 and $w_2 = .5$. The variance of energy prices becomes \$1.15 as a result of the gas substitution. An increase in the share of gas (at the expense of oil) reduces overall energy price volatility. This result derives algebraically because gas prices are less risky than oil prices and because oil and gas prices are less than perfectly correlated. The basic concept, which is the heart of portfolio analysis, is that diversification between risky assets can reduce overall portfolio risk.

In the above illustration, an R&D investment is assumed to lead to the substitution of one fuel for another and this diversification reduces overall risk. Investments that have this result are typically technologies that affect end use demand. A different R&D strategy to reduce energy price volatility is to reduce the variance of oil prices or the variance of gas prices or the covariability between them. The price of oil is a world price influenced by world events rather than by the DOE's R&D programs. In contrast, natural gas prices are determined by domestic supply and demand factors and can be affected by an energy R&D strategy. Increases in the supply of natural gas increase its price stability and tend to weaken its link with oil prices. For instance, suppose that an R&D investment resulted in an increase in the amount of feasible gas reserves at current gas prices. (In economic terms, this increase causes the gas supply curve to become more price elastic.) A short or long term oil price increase would result in the substitution of gas for oil and thereby reduce

TABLE 1

ENERGY PRICE STABILITY
(Illustrations Using Equation (3))

CASE NUMBERS	ILLUSTRATIONS	ENERGY PRICE RISK	σ^2 OIL PRICE	σ^2 GAS PRICE	W_o OIL SHARE	W_g GAS SHARE	σ_{og} OIL & GAS PRICE
1	Base Case	1.410	2.299	0.506	0.634	.366	.9017
2	Increased Diversification	1.152	2.299	0.506	0.50	.50	.9017
3	Severed Price Link	0.992	2.299	0.506	0.634	.366	0
4	Conservation	0.973	2.299	0.506	0.50	.366	.9017
5	Transportation Sector (Base Case)	2.299	2.299	--	1.0	--	--
6	Transportation Sector	1.780	2.299	0.506	0.8	.2	.9017
7	Transportation Sector (NGV and severed prices)	1.492	2.299	0.506	0.8	.2	0
8	Electricity Sector (all)	.541	2.299	0.506	0.042	.958	.9017
9	Electricity Sector (Oil & Gas)	.834	2.299	0.506	0.30	.70	.9017

overall energy price volatility. With increased gas supplies, this substitution can occur without significant gas price increases, which further reduces energy price volatility.

The previous illustration (Case 3) indicates the effect of severing the link between oil and gas prices on energy price stability. The input assumptions are like the base case except that the covariance between oil and gas prices is assumed zero. The result is that overall energy price risk decreases to .992, which is almost 30 percent lower than the base case. The practical implication of this result is important. The risks of oil prices can be reduced by substituting a fuel whose price is uncorrelated with oil prices. A strategy of severing the link between gas and oil prices is potentially promising.

A fundamental point in the portfolio analysis of financial assets is that portfolio risk is minimized by investing in assets whose rates of return are not highly correlated. Balanced portfolios typically contain investments with relatively low covariances. The implication of this result with respect to energy price stability is that stability is enhanced if energy prices are not highly correlated.

The energy price variability model is not intended to consider conservation policies, but it yields an implication worth noting. Assume that an oil conservation strategy improved fuel efficiency so that less oil is consumed, but natural gas consumption is unaffected. In this illustration (Case 4), the share of oil decreases from .634 to .5 as a result of the fuel efficiency improvement. The result is a substantial reduction in overall energy price risk. This result will hold in general, because replacing a fuel with a riskless variable will always reduce overall risk.

This result holds only with respect to fuel prices and not the cost of energy services. Conservation is the substitution of capital (or labor) for energy. Capital costs may be risky and increase the overall costs of providing energy. The "rate shock" caused by rapidly escalating capital costs of nuclear and coal plants during the 1970's is but one example. Conservation investments are frequently highly risky. Conserving energy necessarily reduces risks due to fuel prices, but it does not necessarily reduce energy price variability.

Conservation, as a strategy for achieving energy price stability, is likely to have its greatest potential where energy prices are the most risky. The transportation sector relies almost exclusively on a single fuel that is volatile historically and is also underpriced by the market. The price of oil reflects neither its environmental cost nor energy security cost. In contrast, natural gas has a lower price variance and is environmentally cleaner. Conserving oil reduces energy price risks more than conserving the same amount of natural gas.

These illustrations refer to the aggregate use of the two fuels. However, fuel use is sector specific. The energy price variability equation can also be applied to each sector. The gas industry requests significant funding for research and development of natural gas vehicles. Prior to the commercialization of these vehicles (Case 5), we assume the market share of oil in this sector to be 100 percent ($w_1 = 1$). The variance of transportation energy prices is estimated to be $2.299, which is simply the variance of oil prices. If natural gas vehicles were to capture, say, 20 percent of the market (in terms of Btu fuel consumption), the variance of transportation energy prices would decrease from $2.299 to $1.78, which represents a reduction of about 23 percent (Case 6). The commercialization of an alternatively fueled vehicle could lead to a substantial contribution in reducing energy price risks in the transportation sector.

An alternative diversification would be to substitute a fuel whose price is not correlated with oil prices. Such a fuel could be natural gas if the oil-gas price link were severed. Under this assumption (Case 7), the covariance term in the above equation becomes zero and the variance of transportation energy prices becomes $1.492, which represents a substantial improvement in energy security. Shifting out of oil yields a major improvement in energy security and shifting into a fuel whose price is uncorrelated with oil prices yields an additional security benefit.

One implication from these illustrative results is that almost any substantial substitution for oil in the transportation sector is a major improvement in energy price stability. In the first illustration, the substitution was from one high risk fuel to another high risk fuel where the prices are positively correlated. The result is a major contribution to energy price stability. In the second illustration, the substitution is to a fuel whose price is uncorrelated with oil prices. An additional major improvement in energy price stability results from diversifying into a fuel whose price is independent of oil prices.

The link between the price of oil and that of any alternative transportation fuel depends on the supply price elasticity of that fuel. In the event of an oil price shock, the transportation sector would increase the demand for the alternative fuel. If the supply function for this fuel is price elastic, the increase in demand could be met without a price rise. More specifically, if the short run supply curve were price inelastic but the long run supply curve price elastic, the fuel would provide more long run price security than short run security. Achieving energy price stability in the transportation sector requires first, shifting out of oil and second, shifting in to a fuel that can meet a substantial increase in demand without an increase in price.

In the next illustration (Case 8), the effect of backing out of oil on the stability of electricity prices is considered. The variances of oil and gas prices are the same as used above. In 1990, 1.25 quadrillion of petroleum were used in the U.S. to generate electricity out of a total 29.58 quadrillion Btu of fossil fuel equivalent required for total generation.[5] For illustrative purposes, we consider electricity to be generated by two fuels: oil and the composite of all other fuels, where the shares are .042 and .958 respectively. The composite

[5] Energy Information Administration, Annual Energy Review, 1990, p. 211

fuel is assumed to have less risky prices than oil and let it equal the variance of natural gas prices. The variance of electricity prices equals

$$\$0.542 = .042^2 \times 2.299 + .958^2 \times .506 + 2 \times .042 \times .958 \times .9017, \text{ or,}$$

$$\$0.542 = .0041 + .4644 + .0726.$$

The contribution of the weighted variance of oil prices is .004 out of a total variance of .542.

Oil prices contribute very little to the total volatility of electricity prices. The above equation probably overstates the oil contribution to electricity price volatility. When oil prices increase, some utilities are able to switch fuels and not bear the oil price risk. Fuel switching occurs in dual fuel power plants and in using alternative fuels in different power plants. The actual covariance between oil prices and fuels used to generate electricity is lower than the covariance between oil and gas prices. Nuclear, hydro and coal generate a large share of electricity and these fuels are not highly correlated with oil prices. Considering the negligible contribution of oil to the variance of electricity prices, it follows that displacing oil in this sector would not contribute to energy price security.

If this illustration were changed so that only the energy inputs of natural gas and petroleum in electricity generation were considered, the shares of these two fuels become .70 and .30 respectively. The separate contribution of these fuels to the variance of electricity prices is estimated as the fuel shares squared and multiplied by the variances of gas and oil, which yields .25 and .21 respectively. Gas makes a larger contribution to electricity price variability than does oil, even though its price risk is much less. One implication is that substituting gas for oil in the electricity generation sector will not contribute to energy price stability. Secondly, further backing out of oil will not enhance energy price stability in this sector.

Some R&D investments in natural gas supplies will not have apparent economic value at current fuel prices, but will only be feasible at higher prices. Such investments may not provide insurance against short term oil price spikes, but may provide security against medium or longer term price increases. A longer term oil price increase would result in the investment becoming feasible and thereby producing a substitution from oil to gas. The implication is that some R&D investments may be desirable for their energy security value even though they are not feasible at current prices. This external benefit reduces the risk of a market failure and is reason for consideration of support Government funding. Estimating the energy security value of an investment requires estimating its effect on energy price variability at alternative fuel prices.

Conclusions

The energy price volatility model suggests that some of the proposed natural gas programs can contribute to energy price stability. The sector most vulnerable to fuel price variations is, of course, the transportation sector. The most effective strategy to achieve energy price stability is to reduce petroleum consumption in this sector. The natural gas vehicle program is therefore recommended as potentially important and worthy of further consideration. At this point, distinguishing the merits of various subprograms is not feasible.

This result further supports the conclusion that the DOE's energy R&D portfolio is not efficiently balanced and an increase in oil and gas research should be a high priority (Sutherland, 1989, p. 39). The DOE has responded favorably and has significantly increased its proposed research with the explicit objective of displacing oil in the transportation sector. The enhanced research and development program for energy security, in the NES, proposes major funding increases in this area. To recommend the further increases proposed by the industry, a careful analysis of incremental benefits and costs is required.

The proposed natural gas supply program is intended to enhance the future supply of natural gas. As explained above, enhanced gas supplies can reduce the volatility of gas prices and severe the link between gas and oil prices. The gas supply program is recommended as a potentially important strategy to ensure energy price stability. The importance of this point merits restatement. Oil price volatility affects directly the transportation and industrial sectors. The residential, commercial and electric utility sectors are not highly oil dependent. (Most oil use in these sectors is concentrated in the Northeast.) However, oil prices have affected gas prices and gas is used extensively in the residential, commercial, industrial and electric utility sectors. Energy price stability is enhanced in these sectors by severing the link between oil and gas prices.

The polymer membrane subprogram of the fuel cell program is recommended because this fuel cell technology is designed to be used in transportation vehicles and can displace oil. This program adds to the diversification to the DOE's alternative fuel vehicles program and thereby reducesits overall risk.

The funding of natural gas technologies used to generate electricity is not recommended on grounds of energy price stability. As explained above, substituting gas for oil in this sector does not improve energy price stability. The DOE currently supports a diversified set of these technologies and further diversification is likely to yield negligible benefits. One argument on behalf of natural gas R&D is that the current DOE budget is not efficiently balanced by being weighted to heavily towards electricity generation. This argument should not be used while, at the same time, arguing for Government R&D to develop gas based generating technologies.

End-use gas technologies that substitute for electricity are also not supported here in grounds of energy price stability. Gas technologies that displace oil in the transportation or industrial sectors can contribute to energy price stability. Displacing oil in the residential and commercial sector has lower potential energy price stability benefits.

Government support for the development of gas using technologies may be warranted on other grounds, such as environmental quality and economic efficiency.