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ENERGY POLICY RESEARCH

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How does one go about conducting energy policy research? In many ways energy policy research is no different from policy research in any other area. We begin by defining the problem and describing the general setting in which the problem exists. We review the relevant literature, focus the research by stating the specific research objectives, and establish an appropriate methodology for conducting the research. We collect our data, formulate models, test results, reformulate if necessary, and communicate results to policy makers.

In this paper we will illustrate some of the differences between energy policy research and policy research in other areas. The fundamental difference is that externalities and equity issues appear to be relatively more important in energy policy analysis than in some other areas.[1] The difference, of course, is a matter of degree—externalities and equity are important in any area. But virtually every major energy policy decision in the past decade turned on a perceived externality or equity issue. The gasohol tax exemption, natural gas price regulation, oil and oil product price controls, entitlements, windfall profits tax, the Clean Air Act—all are examples of policies in which externalities or equity issues were paramount. This is not to say that economic efficiency analysis is unimportant; rather, that efficiency analysis must be coupled with evaluation of externality and equity issues to provide the information needed for energy policy formation.

A second important difference between energy policy analysis and policy analysis in some other areas is the level of technical understanding needed by the economist. Again it is a matter of degree, but knowledge of the technical alternatives is quite important to providing useful analysis. The resource economist should be able to discuss alternatives with researchers from other disciplines, especially the relevant engineering disciplines. Without that knowledge, it is all too easy for advocates of some particular alternative to sway policy makers to support their alternative, which might not be chosen with better information.

The remainder of this paper is divided into five parts. First, we provide some background information on energy alternatives as an attempt to briefly describe the broad energy situation. Next, we characterize the energy problem as a national security problem and discuss energy policy in this context. The third and fourth sections describe parts of two studies which were designed to provide information for energy policy formation. The final section contains a brief summary and further reflections on energy policy research.

ENERGY ALTERNATIVES

The United States has very large energy resources, but most of the resource is in solid form, while most of our consumption is in liquid form. An estimated 98–99 percent of our resources are in solid form (coal, shale, nuclear) while oil and natural gas (fluids) make up about three-fourths of our consumption (Tyner, 1980). The discrepancy between the form

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[1] Energy policy analysis is similar to food policy research in that externality and equity issues are very important in both areas.

of our consumption and the availability of domestic energy resources is at the heart of our perceived energy problem. Most of the alternatives are concerned with either reducing demand or increasing domestic fluid energy supplies. We will consider five different approaches: 1) energy conservation, 2) increase the domestic oil supply, 3) change consumption from liquids to solids, 4) convert other sources to liquids, and 5) move to renewable energy sources.

Energy Conservation

Energy conservation has been called our cheapest energy source. Up to a point this is correct. The cost of better insulation and more efficient energy management techniques is generally far less than the cost of the energy that would have been consumed. Significant amounts of energy can be saved with improved architectural design in buildings. Large amounts of energy can and will be saved with the more fuel efficient automotive fleets.

In general, better energy management can lead to significant savings of energy both in industry and in the home. In fact, over the past few years significant savings in energy have been achieved in the industrial sector. Many industries have reduced energy consumption by 30 percent or more in the last four years. Demand forecasts for 1990 and 2000 have been plummeting in recent years.

Energy conservation can be stimulated by a variety of policy alternatives. Building codes and standards have been modified to increase conservation. Regulations on thermostat settings, reduced highway speed limits, automobile fuel economy standards, and various tax incentives have been implemented. Perhaps the most powerful incentive for increased energy conservation has been higher energy prices. Until recently oil prices were regulated and oil was priced at less than its replacement cost. Natural gas prices are still regulated. Hence, price induced conservation has been less than it would have been with market pricing of energy commodities.

Increase the Oil Supply

The second approach to our energy problem is to increase the oil supply. Oil prices have been deregulated and natural gas prices will be deregulated by 1985 or sooner. Since the 4th quarter of 1980, all time drilling records have been set as the pace of drilling activity increased. Price deregulation has been and will continue to be a stimulus to increasing U.S. oil and gas reserves. However, this "supply side" strategy alone will not solve the oil import problem–according to the best estimates available, there just is not that much oil left to be discovered in the United States.

Change Consumption from Liquids to Solids

The third approach to our energy problem is to change consumption from liquids to solids. The most direct means of accomplishing this is to switch from using fuel oil for electricity generation and industrial process heat to using coal to generate that heat. More than half of the utility and industrial process heat using fuel oil could be converted to coal thereby saving over 1 million barrels per day of oil.

Another means of changing consumption from liquids to solids which is longer term in nature is to convert a portion of our existing vehicle fleet from its current status of liquid consumption to electric vehicles. The electricity could be generated from coal or nuclear power thereby accomplishing the change from consuming liquids for transportation to using solids via the electric vehicle. Clearly this is a longer term option but it does offer potential for changing consumption from liquids to solids.

Convert Other Sources of Energy to Liquids

The fourth approach to our energy problem is to convert other sources of energy to liquids. This is the so called syn-fuel option. Liquid fuels can be made from coal, oil shale, or tar sands—enough to last at least a century. The United States has very large reserves of coal and oil shale. About 10 years ago it was believed that oil could be produced from oil shale for around $8 per barrel. Since that time the price of oil shale crude has always remained a step ahead of the price of crude oil. Current estimates of producing crude from oil shale range about $35 to $50 per barrel. The cost of producing oil from coal lies $10–$20 above this range.

Renewable Energy Resources

The fifth approach to handling our energy problem is to move in the direction of using more renewable energy sources. The ultimate source of renewable energy is the sun, but other closely related energy sources are included in this category. Biomass, wind power, ocean thermal, hydropower, and other energy sources which are directly or indirectly related to solar energy are usually included. The potential for producing energy from agriculture also falls within this category.

ENERGY AND NATIONAL SECURITY[2]

With this brief description of the major technical categories of energy alternatives, we now turn to the relationship between energy and national security. U.S. dependence on foreign nations to supply our liquid energy demand and the potential economic, political, and military costs of this dependence is what I call the national security externality. The source of policy concern is the proposition that the United States is less secure, the larger the fraction of our energy consumption that comes from foreign sources. In particular, we are said to be much less secure in this sense than our chief adversaries. The potential for political blackmail is thought to increase directly with the proportion of oil imports subject to sudden disruptions, as the Arab embargo dramatically illustrated.

The probability of a serious disruption of oil imports may be very small. Nevertheless, if it occurred the cost in weakened military power, domestic output, and consumer well-being would be very high. The risk is one of low probability-high potential loss, analogous to the risks associated with nuclear accidents, earthquakes, and 100-year floods.

Ordinary markets cannot handle low probability-high loss risks. Hence, private decisions concerning goods and services subject to such risks will not take into account the expected costs to society associated with them. As a result, the costs and prices of goods and services for which oil is an input will be too low, and too much of them will be produced and consumed, compared to an efficient allocation of resources inclusive of all social costs. In effect, an independence (risk of disruption) premium that should be included in prices is ignored in private decisions to produce and consume. Economic efficiency-cum-independence requires that the expected costs of a disruption of oil supply be included in market prices so that the independence premium is duly reflected in people's decisions.

There are several policy options designed to deal with the national security externality. These include a tax on oil, an oil reserve, subsidies for oil alternatives, and a synthetic fuels requirement.

In previous work, we have argued that an appropriate corrective for this externality would be a tariff on imported oil and a tax on domestic production (Tyner and Wright; Tyner, 1979). In essence, the tax and tariff would place a value on (price) the national security externality; hence, the level of the tax and tariff and the associated level of imports would be policy variables. Any energy alternative (discussed above) could be developed if its production cost were less than the world oil price plus the tariff.

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[2] *This section is based partly on Tyner and Wright.*

Another option which has been implemented on a small scale is the strategic petroleum reserve (SPR). SPR is designed to work as an oil savings account which can be drawn upon quickly in the event of a sudden supply disruption. Several studies have estimated the benefits and costs of a SPR, estimated the optimal size for the SPR, and examined the implications for alternative drawdown strategies in the event of a supply disruption.

Two other options which have received a lot of attention are a synthetic fuels requirement and subsidies for synthetic fuels. The synthetic fuels requirement would work something like the auto fuel economy standards. For the auto fuel standards, the sales of each company must meet a preset mileage standard. Each company may choose the way it meets the standard.

Similarly, for the synthetic fuels requirement, each oil marketer would be required to include X percent domestic synthetic fuels in their product sales. The company would choose the source and technology to meet its requirement. The required percentage would rise through time. Subsidies for synthetic fuels take a variety of forms, some of which will be discussed in the next section on shale oil policy analysis. As we proceed through the shale oil study and the subsequent section on comparison of energy alternatives, please bear in mind this broader economic and technical context of energy policy analysis.

SHALE OIL POLICY ANALYSIS[3]

The Office of Technology Assessment (OTA) shale oil study evaluated economic efficiency, physical and technical, environmental, and socioeconomic aspects of oil shale development for four different levels of production. Here we will concentrate on the efficiency analysis, but the study provided a complete assessment in all these areas. The study was requested by Congress to provide guidance on policy alternatives to stimulate oil shale development and evaluation of the impacts of shale development.

OTA was specifically requested to compare alternative policies designed to stimulate oil shale development.[4] The following nine options were evaluated in the study:

- Construction grants of a prespecified percentage of total construction costs (both 33 and 50 percent were evaluated);
- A $3 per barrel production tax credit on each barrel produced (prior to upgrading);
- Low interest government loans (70 percent of total capital costs at 3 percentage points below the market rate was analyzed);
- A government guaranteed price (price support) of $55 per barrel of hydrogen-upgraded syncrude;
- A product purchase agreement with the government at the same level as a price support;
- An increased depletion allowance (evaluated at 27 percent compared to the current 15 percent);
- An additional 10 percent investment tax credit;
- Accelerated depreciation (a 5 year write-off period was tested); and
- Government loan guarantees.

Each of these was compared with a base case (no subsidy) alternative. The study was done utilizing a computerized discounted cash flow model (GEN2) which incorporates risk and uncertainty through Monte Carlo simulation (Tyner and Kalter, 1977 and 1978). Since documentation is available, the model will not be described here. Four key outputs of the

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[3] *Much of this section is drawn from the Office of Technology Assessment oil shale study. This author was a member of the advisory panel for that study.*

[4] *All these alternatives represent different forms of subsidization of oil shale. If the excise tax and import tariff discussed above were enacted, we would not need or want to subsidize alternatives to oil. But Congress has in the past shown a clear preference for subsidies over taxes to correct perceived inequities or externalities.*

model simulations were used for purposes of comparison. They included expected profit or the expected return in excess of a required after tax return on investment,[5] risk measured both as the probability of incurring a loss on the investment and the variability in profit outcomes, the breakeven price (the constant price through time needed to earn the minimum required rate of return) and the cost to the government of an incentive.[6]

Economic Feasibility of Oil Shale

Tables 1 and 2 summarize the analytical results at the 12 and 15 percent rates of return, respectively. The results, although in terms of a single 50,000 barrel per day oil shale facility, would be those expected, for an average, over a number of such plants. Note that the assumed rate of return (discount rate) is critical to the profitability of the "base case." At 12 percent, expected present value profit is $220 million with only a 9 percent probability of loss and a $48.20 per barrel breakeven price. At 15 percent expected profit is a negative $196 million with a 93 percent probability of loss and a $61.70 per barrel breakeven price. Thus, the breakeven price must increase by 28 percent to achieve profitability if a 15, rather than 12, percent rate of return is required to encourage investment commitments.

The nine government incentives tested vary greatly in their impact on expected profit and risk, the type of risk impacted, sensitivity to the required rate of return and the marginal tax rate of the participating firm, and the cost to the government. Also, the administrative burden and transactions costs of implementing the various incentives can vary widely. For example, most non-tax incentives, such as purchase agreements, price supports, construction grants, low interest loans, and loan guarantees, require a greater administrative cost than tax credits and deductions. Thus, a single incentive was unlikely to emerge from the analysis as "superior" to all others because of the diverse criteria used to judge the alternatives, the differential impact of exogenous parameters, and because firms in different circumstances will tend to prefer different kinds of incentives to avert the risks that prevent them from undertaking shale oil projects.

As a part of the study, firms interested in oil shale ventures were polled as to their preferences among the various incentives. The results of that survey were quite interesting. Of course, what they revealed was that firms preferred the incentives which benefited them the most. The diversity among firms was such that firm preferences varied quite a lot. Firms with excess tax credits did not like the extra investment tax credit or accelerated depreciation. Small firms liked the guaranteed loan option; large firms tended to oppose it.

In general, a number of factors must be weighed if the government is to foster an incentive program to encourage the development of an oil shale industry. The choice of incentive(s) will not be made on purely economic efficiency grounds (from either the viewpoint of the industry or the society). Table 3 summarizes a number of the factors discussed above as well as other concerns like promotion of competition, minimization of administrative burden and provision of proper incentives to promote efficient use of resources. From this overall perspective, OTA concluded that production tax credits, purchase agreements, and price supports were the preferred subsidy mechanisms if the government decided it were necessary (or desirable) to provide subsidies.

In addition to examining the subsidy and economic efficiency issues, the OTA study also assessed environmental and socioeconomic impacts. Estimates were made of the amount of each type of air and water pollutant expected from a 50,000 BBL/day oil shale plant. Also,

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[5] *Profit was measured as after tax net present value calculated using continuous discounting at a stipulated real after tax rate of return. Several rates of return were tested including the 12 and 15 percent values reported here. At a 12 percent inflation rate, these are equivalent to 25 and 29 percent nominal after tax rates of return, respectively.*

[6] *Government cost was calculated as the present value of the government subsidy less increased tax revenues (tax receipts above the without incentive case). All government costs were present valued using a 10 percent real discount rate (OMB, Circular A-95).*

TABLE 1

SUBSIDY EFFECT AND NET COST TO THE GOVERNMENT OF POSSIBLE OIL SHALE INCENTIVES[a]
(12-PERCENT RATE OF RETURN ON INVESTED CAPITAL[b])

Incentive	Total Expected profit[c] ($ million)	Change in expected profit ($ million)	Standard deviation[d] ($ million)	Ratio of Change in expected profit to standard deviation	Probability of loss	Breakdown price ($)	Total expected cost to Government ($ million)	Ratio of Change in expected profit to Government Cost
None	$220	$ 0	$219	0.0	0.09	$48.20	$ 0	NA
Construction Grant (50%)	707	487	205	2.4	0.00	34.00	494	.98
Construction Grant (33%)	542	321	210	1.5	0.00	38.70	327	.98
Low Interest Loan (70%)	497	277	219	1.3	0.00	43.40	453	.61
Production Tax Credit ($3)	414	194	219	0.9	0.01	42.60	252	.77
Price Support ($55)	363	142	171	0.8	0.01	NA	172	.83
Increased Depletion Allowance (27%)	360	140	247	0.5	0.05	45.70	197	.71
Increased Investment Tax Credit (20%)	299	79	216	0.4	0.05	45.80	87	.90
Accelerated Depreciation (5 years)	296	76	215	0.4	0.05	46.00	79	.96
Purchase Agreement ($55)	231	11	126	0.1	0.03	NA	0	NA

[a] All monetary values are in constant 1979 dollars.

[b] With 12-percent annual inflation a 12-percent real discount rate is approximately a 25-percent nominal aftertax rate of return. The calculation assumes a $35/bbl price for conventional premium crude that escalates at a real rate of 3 percent per year. Thus, the predicted $48/bbl breakeven price for the 12-percent discount rate will be reached in 11 years, or in the fifth year of production. Therefore, in narrow economic terms, oil shale plants starting construction now, which assume a 12-per discount rate, will be profitable over the life of the project without subsidy. The calculations are for a 50,000-bbl/d plant costing $1.7 billion.

[c] Expected profits is the return in excess of a 12-percent discounted cash flow rate of return on investment.

[d] Standard deviation is a measure of the dispersion of possible profit outcomes arount expected profit.

Source: OTA, 1980

TABLE 2
SUBSIDY EFFECT AND NET COST TO THE GOVERNMENT OF POSSIBLE OIL SHALE INCENTIVES[a] (15-PERCENT RATE OF RETURN ON INVESTED CAPITAL[b])

Incentive	Total Expected profit[c] ($ million)	Change in expected profit ($ million)	Standard deviation[d] ($ million)	Ratio of Change in expected profit to standard deviation	Probability of loss	Breakeven price ($)	Total expected cost to Government ($ million)	Ratio of Change in expected profit to Government Cost
None	$196	$ 0	$153	0.0	0.93	$61.70	$ 0	NA
Construction Grant (50%)	281	477	135	3.5	0.00	40.60	494	.96
Construction Grant (33%)	119	315	140	2.2	0.19	47.70	327	.96
Low Interest Loan (70%)	81	277	153	1.8	0.23	54.70	453	.61
Production Tax Credit ($3)	–61	135	153	0.9	0.63	58.30	252	.54
Price Support ($55)	–88	108	122	0.9	0.77	NA	172	.63
Increased Depletion Allowance (27%)	–110	86	170	0.5	0.75	57.20	197	.44
Increased Investment Tax Credit (20%)	–131	65	150	0.4	0.77	58.80	87	.75
Accelerated Depreciation (5 years)	–127	69	149	0.5	0.76	58.90	79	.87
Purchase Agreement ($55)	–150	46	102	0.4	0.92	NA	0	NA

[a] All monetary values are in constant 1979 dollars.

[b] With 12-percent annual inflation a 15-percent real discount rate is approximately a 29-percent nominal aftertax rate of return.

[c] Expected profit is the return in excess of a 15-percent discounted cash flow rate of return on investment.

[d] Standard deviation is a measure of the dispersion of possible profit outcomes arount expected profit.

Source: OTA, 1980

TABLE 3
EVALUATION OF POTENTIAL FINANCIAL INCENTIVES FOR OIL SHALE DEVELOPMENT

Incentive	Subsidy effect	Risk-sharing effect	Financing effect	Promotion of economic efficiency	Minimization of administrative burden	Promotion of competition	
						Effect on firms	Firm preferences
1. Production tax credit ($3/bbl)	Strong; subsidizes product price	Moderate; shares risk associated with price uncertainty (If tax credit varies with product price)	Slight; Improves project economics	Slight adverse effect; distorts product price	Minimal administrative burden	Benefits firms with large tax liability and strong financial capability	Supported by relatively large firms
2. Investment tax credit (additional 10%)	Strong; subsidizes investment cost	Moderate; shares risk associated with investment cost uncertainty	Slight; Improves project economics	Moderate adverse effect; distorts input costs; favors capital-intensive technologies	Minimal administrative burden	Benefits firms with large tax liability and strong financial capability	Supported very strongly by most firms; however, firms that would not be able to use the investment tax credit do not favor its enactment
3. Price support	Strong; subsidizes product price (if contract price is higher than market price)	Moderate; shares risk associated with price uncertainty	Moderate; Improves borrowing capability	Slight adverse effect; distorts product price	Moderate administrative burden	Benefits all firms except those with very weak financial capability	Moderately supported by a wide range of firms
4. Loan guarantee	Slight; subsidizes investment cost	Moderate; shares risk of product failure	Strong; Improves borrowing capability	Slight adverse effect; distorts input costs; favors capital-intensive technologies	Moderate administrative burden	Benefits firms wth weak financial capability	Supported by firms with limited debt capacity
5. Subsidized interest loan (70% debt at 3% below market rate)	Slight; subsidizes investment cost	Moderate; shares risk of project failure	Strong; Government provides capital	Slight adverse effect; distorts input costs; favors capital-intensive technologies	Moderate administrative burden	Benefits firms with weak financial capability	Supported by firms with limited debt capacity
6. Purchase agreements	Strong; but less than price supports	Strong; shares risk of price uncertainty	Moderate; Improves borrowing capability	Slight adverse effect; distorts product price	Moderate (normally more than price supports)	Benefits all firms but those with very weak financial capability	Moderate, but less than for price supports
7. Block grant (33 & 50% of plant cost)	Strong; neutral subsidy	None	Strong; Government provides capital	No adverse effect	Moderate administrative burden	Benefits all firms	Supported by firms in widely varying financial circumstances
8. Accelerated depreciation (5 years)	Moderate; subsidizes investment cost; maximum subsidy effect is limited by Federal corporate income tax rate and interaction with depletion allowance	Moderate; shares risk associated with investment cost uncertainty	Slight; improves project economics	Moderate adverse effect; distorts input costs; favors capital-intensive technologies	Minimal administrative burden	Benefits firms with large tax liabilities and strong financial capability	Supported by large, integrated oil companies
9. Percentage depletion allowance (27%)	Moderate; subsidizes product price; value of subsidy increases as the need for the subsidy decreases	None; increases risk associated with price incertainty	Slight; improves project economics	Moderate adverse effect; distorts product price in a variable and	Minimal administrative burden	Benefits firms with large tax liabilities and strong financial capability	Not supported

Source: OTA, 1980 and Resource Planning Associates, Inc.

the significance of each of these estimates was described in terms of effect on human health, visibility, or other appropriate measures. General summary estimates of the environmental impacts were provided for each size of shale industry included in the study.

At any industry size below 400,000 BBL/day, environmental impacts could be controlled to meet the standards of the amended Clean Air Act. However, institutional and environmental barriers were found to be critical at the 1 million barrel per day production level. In fact, the 1 million barrel per day level cannot be reached with current or projected environmental control technology under the environmental laws and regulations in effect today.

OTA attempted to summarize the effect of each industry size on achievement of several objectives of oil shale development. Figure 1 displays the essence of these results and highlights the trade-offs and degree of attainment of various objectives for each level of shale oil development. Table 4 highlights the major constraints to implementing the four levels of production.

The OTA oil shale study attempted to evaluate oil shale potential and problems from a wide range of perspectives. I have only scratched the surface in reporting on a 517 page document. What I would like to emphasize is that the study represents for one syn-fuel option the kind of broad ranging analysis that is needed for all of the energy alternatives we discussed earlier.

COMPARISON OF ENERGY ALTERNATIVES[7]

Currently underway at Purdue is a study which is attempting to compare the efficiency, equity, and environmental implications of major energy alternatives.[8] This study draws upon other work such as the OTA oil shale study for much of its data. It is interdisciplinary involving researchers in civil, mechanical, electrical, and industrial engineering, economics, political science, sociology, and agricultural economics.

FIGURE 1

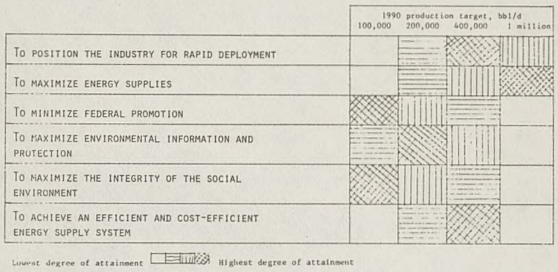

TABLE 4
CONSTRAINTS TO IMPLEMENTING FOUR PRODUCTION TARGETS

	1990 production target, bbl/d			
	100,000	200,000	400,000	1 million
Possible deterring factors	Severity of impediment			
Technological				
Technological readiness	None	None	None	Critical
Economic and financial				
Availability of private capital	None	None	None	Moderate
Marketability of the shale oil	Possible	Possible	Possible	Possible
Investor participation.	None	Possible	Possible	Possible
Institutional				
Availability of land	None	None	Possible	Critical
Permitting procedures	None	None	Possible	Critical
Major-pipeline capacity.	None	None	None	Critical
Design and construction services	None	None	Moderate	Critical
Equipment availability	None	None	Moderate	Critical
Environmental				
Compliance with environmental regulations	None	None	Possible	Critical
Water availability				
Availability of surplus surface water	None	None	None	Possible
Adequacy of existing supply systems.	None	None	Critical	Critical
Socioeconomic				
Adequacy of community facilities and services	None	Moderate	Moderate	Critical

SOURCE: Office of Technology Assessment.

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[7] *This section is based upon Tyner, Binkley, and Matthews.*

[8] *The results reported in this paper are from a draft report of the efficiency analysis and will change somewhat in the final report.*

The study is designed to rely upon experts in each energy area for the primary data. These experts used data from their own research, from the literature, or any combination. Three different levels of development are evaluated for each area:

A. business-as-usual
B. accelerated development
C. maximum feasible development[9]

Basically, the study uses the standard benefit cost approach and computes present values of benefits and costs, net benefits, internal rate of return, and resource cost for each energy area. The time period is 1981 through 2020. At present there are five areas included in the study: shale oil, coal liquids, improved auto fuel economy, biomass alcohols, and railroad electrification. Other areas are being added. Table 5 displays the resource costs for each area at real discount rates ranging between 0 and 15 percent.

After evaluating other options, total enumeration was chosen as the best way of comparing the energy alternatives. With five areas, there are 4^5 possible combinations of levels of development for the different areas–one of each of the three development levels plus no development for each area. Figure 2 contains a plot of the 1024-combinations of investments with present value of total cost plotted agains net benefits. A smoothed envelope curve is drawn through the most efficient combinations. It is interesting to examine some of the efficient combinations. These are indicated by the letters in Figure 2 and are delineated in Table 6.

From this, we see that important investments appear to be auto fuel economy (especially at low levels), rail electrification, and shale oil liquids. Biomass does not come in except at very high levels of funding.

It would be interesting to see how current policy compares with the most efficient investments in the context of this analysis. Current policy cannot be precisely characterized by

TABLE 5
RESOURCE COSTS

Area and Scenario		Discount Rate			
		0	5	10	15
Shale Oil	A	26.95	32.21	40.39	51.39
	B	28.41	34.32	43.03	54.39
	C	29.18	35.73	45.04	56.96
Coal Liquids	A	34.60	40.69	50.46	63.80
	B	37.00	42.82	52.31	65.61
	C	40.24	46.08	55.20	68.58
Auto Fuel Economy	A	22.16	25.37	31.70	40.82
	B	26.90	32.49	41.49	53.25
	C	31.92	38.23	47.12	57.95
Biomass Alcohols	A	55.80	59.00	62.60	66.10
	B	49.60	53.40	58.10	63.20
	C	48.90	52.10	56.80	62.40
Rail Electrification	A	21.63	22.82	26.36	32.82
	B	21.99	23.41	27.26	34.12
	C	22.95	24.88	29.30	36.71

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[9] *The definitions for these areas and other details on the structure and methodology of this study are contained in Tyner, Binkley, and Matthews, which is available from the authors.*

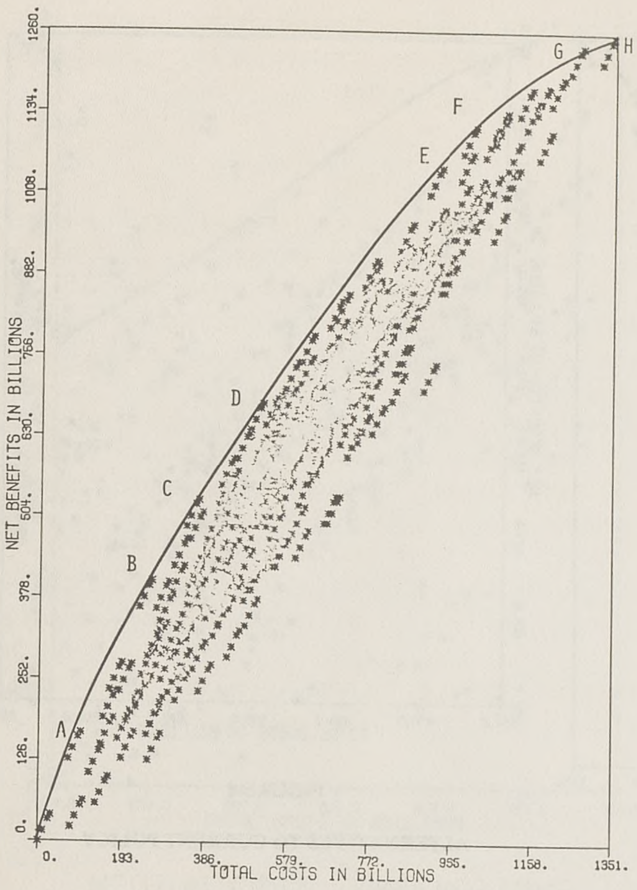

FIGURE 2

ALL COMBINATIONS

TABLE 6
ENVELOPE CURVE COMBINATIONS

	AREAS*			
POINTS	AUTO	SHALE	COAL	BIOMASS
A	A			
B	A	A		
C	A	B		
D	A	B	B	
E	A	C	C	
F	B	C	C	
G	B	C	C	C
H	C	C	C	C

***All point combinations represent four points with increasing levels of rail electrification.**

the scenario levels used here, but for purposes of illustration, we can approximate it. We will assume that current policy could best be summarized as follows:

auto fuel economy – B
shale oil – A
coal liquids – A
biomass – B
rail electrification – 0

Figure 3 shows the point which represents this combination of policies and investment strategies. From an efficiency perspective, all combinations to the left (lower cost and same or

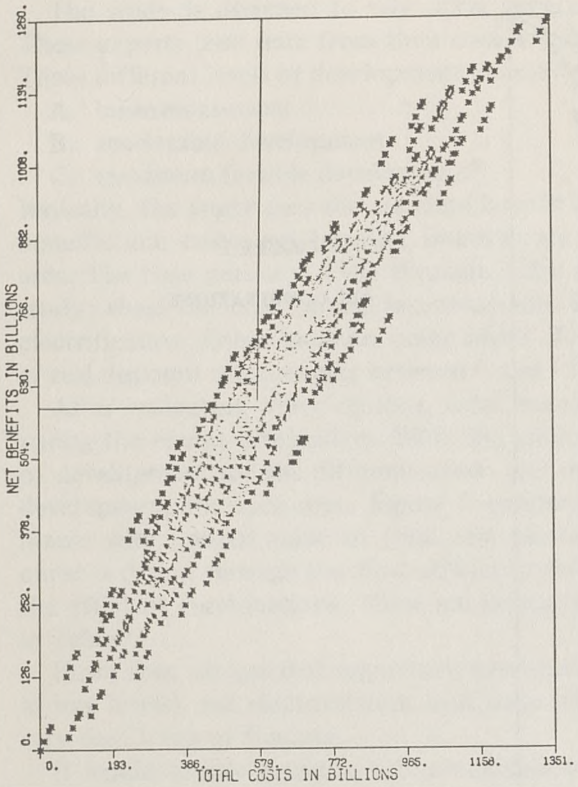

FIGURE 3

ALL COMBINATIONS

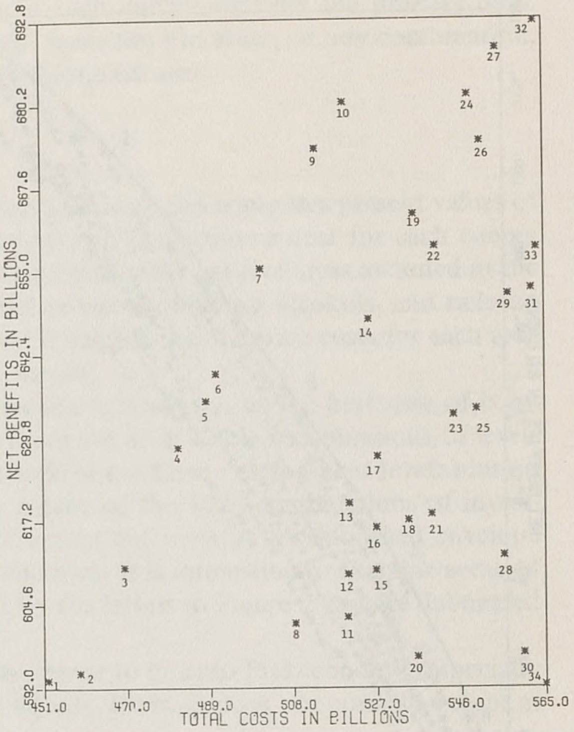

FIGURE 4

ALTERNATIVES TO CURRENT POLICY

higher benefits) and above (same or lower costs but greater benefits) that point represent more efficient combinations.

Figure 4 illustrates the group of points contained in that more efficient set, a total of 33 points. These data indicate that roughly the same benefits could be achieved as under present policy with up to a 20 percent lower cost (point 1) or 17 percent greater benefits could be obtained for the same cost (point 32). Alternatively, 11 percent greater benefits could be achieved at 11 percent lower cost (point 7). Of course, the social, equity, and environmental consequences of a policy change would have to be weighed against the efficiency gains. Also, this result illustrates the vast importance of uncertainty in energy policy analysis. With these data, the difference between current policy and the most efficient policy is 20 percent. Yet, the uncertainty in the cost and yield data that goes into such an analysis is at least that large and probably larger. Sensitivity analysis and other means of handling uncertainty are essential for good energy policy work.

In order to make more detailed comparisons, it is helpful to center attention on particular segments of the graph in Figure 2. We have divided it into three segments, representing low, medium, and high levels of investment and will provide further analysis for medium levels of investment in this paper.

Medium Cost Combinations

Figure 5 displays the cost-benefit combinations at mid-levels of investment. Again we have included a (smoothed) envelope curve representing the maximum net benefits which can be attained for each level of cost. We will illustrate the use of this graph by selecting

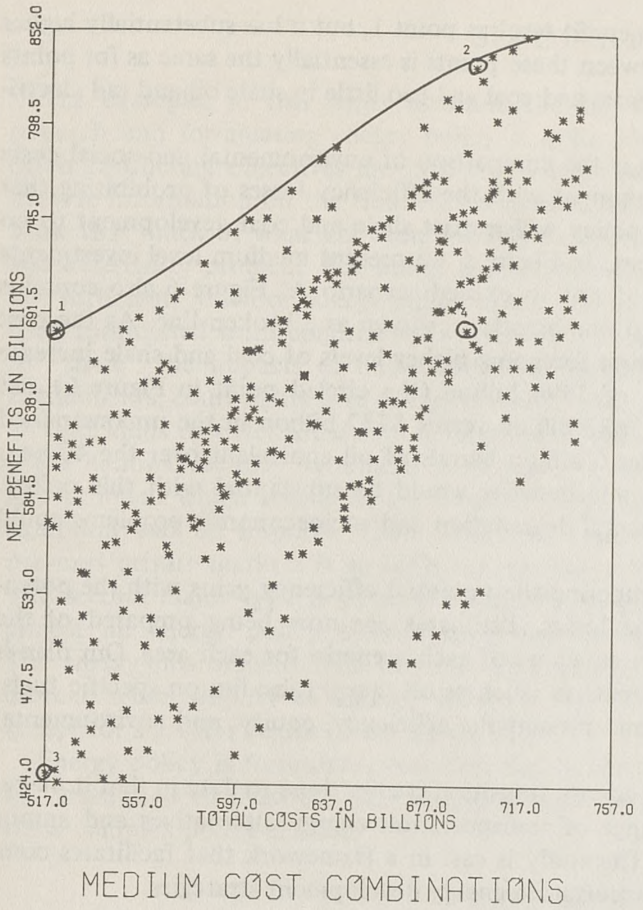

FIGURE 5

TABLE 7
MEDIUM COST COMBINATION POINTS

Area or Value	Points 1	2	3	4
Rail electrification	C	B	A	B
Shale oil	C	C	0	A
Coal liquids	0	B	B	B
Auto fuel economy	A	A	A	A
Biomass alcohols	0	0	C	C
Total cost (p.v. mil. $)	519730	697145	517429	693747
Net benefits (p.v. mil. $)	680252	832312	428932	682392

four points for further analysis. Points 1 and 2 are on the envelope curve and points 3 and 4 are interior points dominated by points 1 and 2. The combinations represented by the four points are described in Table 7.

First we compare points 1 and 3. These two points represent combinations with approximately the same total present value cost but with significantly different benefits. Present value of costs is between $517 and $520 billion. Point 1 on the envelope curve has net benefits of $680 billion whereas point 3 in the interior region has net benefits of $429 billion, 63 percent of the efficient value. By examining Table 7, it appears that most of the misallocation reflects over-investment in biomass alcohols and coal liquids and underinvestment in rail electrification and shale oil.

Point 4 represents about the same benefit level as point 1, but it has substantially higher (33 percent) costs. The difference between these points is essentially the same as for points 1 and 3—too much investment in biomass and coal and too little in shale oil and rail electrification.

Another interesting policy question is the comparison of environmental and social costs of high levels of coal and shale development with the efficiency losses of prohibiting that development. Current environmental policy will restrict shale and coal development to no greater than the A level of development. In Figure 6 we present medium level investments with coal and shale liquids constrained not to exceed scenario A. Figure 6 also contains the envelope curve for all medium cost combinations, shown as a broken line. As the cost level increases, the efficiency losses from foregoing higher levels of coal and shale increase significantly. At a present value cost of $594 billion (the circled point in Figure 6), net benefits in the constrained case are $633 billion versus $737 billion in the unconstrained case, a decrease of 14 percent or over 6 billion barrels of oil equivalent over the 40 year period. Clearly the loss in net economic benefits would be substantial with this policy. However, the difference in environmental degradation and socioeconomic problems could also be large.

The policy decision is made by comparing the potential efficiency gains with the potential environmental and socioeconomic losses. Estimates are now being prepared of the environmental and socioeconomic consequences of each scenario for each area. Our plan is to then evaluate a set of policy alternatives (such as oil taxes, subsidies on specific fuels, and changes in environmental laws) and present the efficiency, equity, and environmental consequences of each alternative.

This research is unique among the energy transition studies done to date in that it makes direct comparisons among a wide range of transportation energy alternatives and among levels of development of each area. The study is cast in a framework that facilitates comparison of alternative policies and transportation energy development strategies.

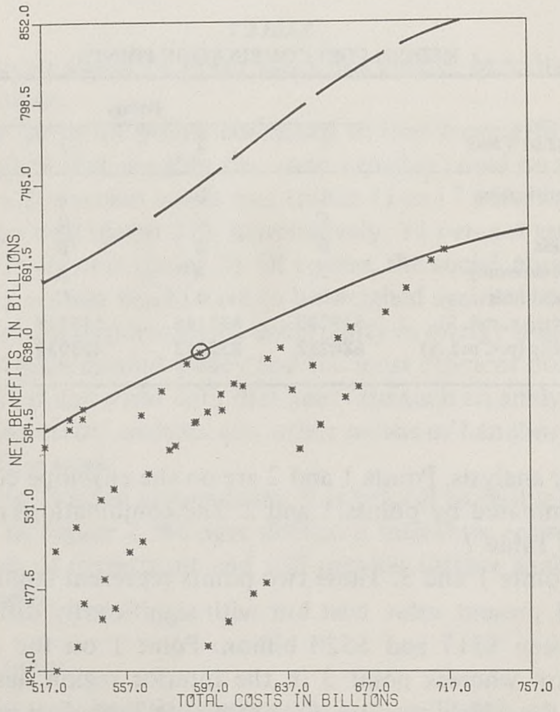

FIGURE 6

MEDIUM COST COMBINATIONS EXCLUDING B AND C COAL AND SHALE

SUMMARY

The examples in this paper illustrate the fact that conducting realistic energy policy research and formulating energy policy is quite complex because so many different and often conflicting objectives are involved. Energy policy research that is to be useful must provide information on the trade-offs related to these divergent objectives. We have tried to show that much of what has been publicly viewed as an energy problem is really an equity and externality problem. For public policy purposes, efficiency analysis of energy issues is not sufficient. Much of energy policy in the past (and I suspect for the future as well) has been formulated from concern with equity or externality issues. A key equity issue is how to "share" the impacts of higher OPEC oil prices, which led us into oil price controls, entitlements, court fights over energy severance taxes, and the like.

Two kinds of externalities are of prime importance for energy policy analysis. The first is the national security externality. The perceived energy problem is really a national security problem which results in a divergence between the social and private cost of oil consumption and oil imports. There exists an unpriced national security externality which prevents private markets from achieving optimal production, import, or consumption levels. The second major type is environmental externalities. Almost all energy alternatives and almost all energy policy options have environmental consequences–some quite severe. The energy-environment trade-off is a very important issue in evaluating syn-fuels policy. In a broad sense, we may be asking, "How much environmental degradation are we willing to accept for a greater degree of energy security?"

Energy policy is formulated and executed in this sort of balancing act milieu. This paper has attempted to illustrate how energy policy research can bring information to bear on these complex policy choices.

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The examples in this paper illustrate the fact that conducting credible energy policy research and formulating energy policy is quite complex because so many different and often conflicting objectives are involved. [illegible]

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