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POLICY INCENTIVES FOR FLUIDIZED BED COAL CONVERSION

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ABSTRACT

Fluidized bed combustion is a commercially available technology to burn coal. However, due to high capital costs, the technology is not economically feasible. In this research, a cash flow model was used to analyze the effect of several policy incentives, and to determine if the effectiveness of the incentives is a function of capital investment. It was found that tax credits are more effective than subsidies, accelerated depreciation has only a weak effect, and that an additional 20 percent tax credit is needed to exceed a minimum acceptable return on investment of 17 percent. The effectiveness of the incentives increases with increasing capital investment. A program is outlined to provide an additional 20 percent tax credit, at a cost of $6 billion but reducing oil imports by 8.7 percent.

Reducing imported oil consumption became a major national priority in the late 1970's. Meeting a substantial fraction of the crude oil requirements of the nation by importing from a potentially unstable cartel has dangerous foreign policy, national defense, and balance of trade implications.

Due to the rapid fuel cost increases, industries are examining ways of displacing natural gas and fuel oil with less costly and more available fuels. One of the most powerful concepts is converting industrial boilers to fire coal using fluidized bed combustion (FBC) technology. This method employs a sorbent (limestone or dolomite) which is added with coal to a fluidized bed and then reacts with the sulfur in the coal to lower SO_2 emissions. However, this

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technology is presently not economically feasible due to high capital costs. The return on investment for coal conversions using fluidized bed technology ranges from 8-14 percent, which is lower than the minimum return on investment considered acceptable by industries [1]. In order to develop fluidized bed technology and as a method of reducing oil imports, incentives must be provided by the federal government to make the return on investment more attractive. [2]

The purpose of this study is to use a previously developed cash flow model to analyze policy incentives for effectiveness in encouraging industrial coal conversions. The model was used to address the following two issues: What effects do tax credits, subsidies and accelerated depreciation have on the economic feasibility of conversion to coal-fired fluidized bed boilers? Is the effect of policy incentives a function of capital investment? After identifying the least-costly policy incentive needed to stimulate FBC investments, an implementation program is outlined.

CASH FLOW MODEL

The model is described in detail by Keenan and Maguire and is briefly reviewed here [1]. The cash flow model includes the capital cost of the boiler, depreciation, pre-tax savings and income tax. The capital outlay includes the initial investment, working capital and salvage value. It is assumed that the initial investment occurs equally during the first two years, and that the facility becomes operational at the end of the second year. Depreciable life for tax purposes of the boiler and auxiliary equipment is five years according to the schedule shown in Table 1. Depreciable life for the buildings is fifteen years. The depreciation method is 175 percent of declining balance, with conversion to straight line when advantageous. Working capital is the amount of money needed to stock the new facility with a sixty day coal supply and a thirty day limestone supply. (All data and results are in October, 1981 dollars.)

Table 1
Depreciation Schedule for Cash Flow Model

	Percent of Investment Depreciated (Depreciable Life, Years)			
Year	*2*	*3*	*4*	*5*
1	38	25	19	15
2	62	38	27	22
3	–	37	27	21
4	–	–	27	21
5	–	–	–	21

Table 2
Base Case Values for Input Data

Parameter	*Base Case Values*
Coal Unit Price, $\$/10^6$ Btu	1.351
Residual Oil Price, $\$/10^6$ Btu	4.315
Natural Gas Price, $\$/10^6$ Btu	2.214
Limestone dosage, lb/lb coal	0.33
Limestone Price, $/ton	45.
Coal Heat Value, 10^6 Btu/ton	25.
Electrical demand, fraction of boiler input, Btu	0.01
Electricity cost, $/kwh	0.03
Labor cost, $1000/operator	25.
Ash content of coal, percent	10.
Ash disposal cost, $/ton	10.
Property tax, fraction of investment	0.01
Insurance, fraction of investment	0.01
Maintenance, fraction of investment	0.02
Fuel oil inflation rate	6.6
Natural gas inflation rate	14.1
Coal inflation rate	4.8
Limestone inflation rate	8.4
Electricity inflation rate	1.1
Ash Disposal inflation rate	2.2
Labor inflation rate	9.3
Property Tax inflation rate	10.2
Insurance inflation rate	8.4
Maintenance inflation rate	9.3

Pre-tax savings are the fuel oil and natural gas savings minus the coal and all other operating expenses. The energy displaced by the coal is 65 percent natural gas and 35 percent No. 6 residual fuel oil. The other operating expenses include limestone, additional electrical costs, ash disposal, additional labor requirements, property tax, insurance, and maintenance.

The capital investment, except for the building outlay, is eligible for a ten percent investment tax credit, and an energy tax credit of ten percent, unless otherwise noted. The corporate tax rate is 49 percent.

The cash flow model was programmed to be interactive. It requests the savings, operating expenses, investment, depreciation, and tax information. A cash flow table is calculated for each of seventeen years (two year design/construction plus fifteen years depreciation life of buildings). The base case (or default) values for the various inputs are listed in Table 2. The output of the model is a cash flow table including columns for the investment, depreciation, pre-tax savings, income tax (pre-tax savings minus depreciation times tax rate),

Table 3
Boiler Capacity and Cost Characteristics

Boiler Capacity lb/hr	*Total Investment 10^6 $*	*Building Investment 10^6 $*	*Annual Energy Consumption 10^{12} Btu*	*Additional Labor, Number of Operators*
50	3.84	0.2	0.26	3
100	7.03	.3	.53	3
200	12.88	.45	1.05	4
300	18.56	.6	1.58	4
400	23.83	.75	2.10	4
500	28.82	.9	2.63	5

after tax savings (pre-tax savings minus income tax), net cash flow (after-tax savings – minus investment), and cumulative cash flow (sum of net cash flow through each year). Finally, the internal rate of return (or return on investment) and the payback period are calculated.

Calculations are made for each of six boiler capacities. The characteristics of these units are summarized in Table 3. The rate of return (or, return on investment, ROI) and the payback period is determined for each of these boilers assuming base case values as discussed above. These results which are summarized in Table 4 show a relatively low return on investment (8 to 14%) [1]. As a consequence, the cash flow model was used to determine the impact of various policy options.

Table 4
Payback Period and Return on Investment for Base Case

Boiler Capacity 1000 lb/hr	*Return on Investment, Percent*	*Payback Period, Years*
50	8.4	10.0
100	12.1	8.1
200	13.7	7.3
300	13.1	7.4
400	13.1	7.2
500	14.2	7.0

IMPACT OF POLICY INCENTIVES

This study assumed the existence of a pool of capital, for which coal conversions compete with other non-energy-related projects. Three types of policy incentives were selected. These are increased energy tax credits, subsidies, and accelerated depreciation schedules. They were chosen because they are the principal methods by which government could influence the return on investment of a given project. Other types of policy incentives (such as providing bond revenues) which would provide capital funding were not considered since the existence of a supply of capital was assumed.

The ranges of policy incentives are defined as follows. Energy tax credit increases of 10, 20, 30, and 40 percent were used. Subsidies were taken at 10, 20, 30, 40 and 50 percent. The subsidized amount was considered ineligible for tax credits and depreciation. The net effect of the subsidy was to reduce the investment by the subsidized amount. Accelerated depreciation was handled by changing the depreciable life of the investment (excluding the buildings) to two, three, and four years in accordance with the schedules shown in Table 1.

Table 5
Annual Net Cash Flows for 100,000 lb/hr Boiler – Increased Tax Credit Cases

	Percent Additional Tax Credit				
Year	*0*	*10*	*20*	*30*	*40*
0	-2950.0	-2950.0	-2950.0	-2950.0	-2950.0
1	-1830.0	-1270.0	-710.0	-150.0	410.0
2	213.1	213.1	213.1	213.1	213.1
3	706.6	706.6	706.6	706.6	706.6
4	729.4	729.4	729.4	729.4	729.4
5	788.9	788.9	788.9	788.9	788.9
6	859.0	859.0	859.0	859.0	859.0
7	365.1	365.1	365.1	365.1	365.1
8	461.3	461.3	461.3	461.3	461.3
9	574.1	574.1	574.1	574.1	574.1
10	705.7	705.7	705.7	705.7	705.7
11	858.3	858.3	858.3	858.3	858.3
12	1035.2	1035.2	1035.2	1035.2	1035.2
13	1240.0	1240.0	1240.0	1240.0	1240.0
14	1476.8	1476.8	1476.8	1476.8	1476.8
15	1750.3	1750.3	1750.3	1750.3	1750.3
16	2325.3	2325.3	2325.3	2325.3	2325.3

Table 6
Annual Net Cash Flow for 100,000 lb/hr Boiler – Increased Subsidy Cases

	Percent Subsidy					
Year	*0*	*10*	*20*	*30*	*40*	*50*
0	-2950.0	-2655.0	-2360.0	-2065.0	-1770.0	-1475.0
1	-1830.0	-1647.0	-1464.0	-1281.0	-1098.0	-915.0
2	213.1	170.2	127.3	84.5	41.6	1.3
3	706.6	644.7	582.8	520.9	459.1	397.2
4	729.4	670.5	611.5	552.5	493.6	434.6
5	788.9	730.1	671.3	612.5	553.7	494.9
6	859.0	800.4	741.7	683.0	624.4	565.7
7	365.1	364.1	363.2	362.3	361.4	360.4
8	461.3	460.5	459.7	458.9	458.0	457.2
9	574.1	573.3	572.6	571.8	571.0	570.2
10	705.7	704.9	704.1	703.4	702.6	701.8
11	858.3	857.5	856.8	856.0	855.2	854.5
12	1035.2	1034.4	1033.7	1032.9	1032.1	1031.4
13	1240.0	1239.2	1238.4	1237.7	1236.9	1236.1
14	1476.8	1476.0	1475.2	1474.5	1473.7	1472.9
15	1750.3	1749.6	1748.8	1748.0	1747.3	1746.5
16	2325.3	2324.6	2323.8	2323.0	2322.3	2321.5

The cash flow model was then run to evaluate the effect of these incentives on the economic characteristics of the investment. The annual cash flows for the 100,000 lb/hr boiler are shown in Tables 5, 6, and 7. The incentives are ranked in order of their encouraging effect on ROI in Table 8. The base case refers to the situation of five year depreciable life, no subsidy, and no additional energy tax credit.

Tax credits are more influential than subsidies in determining economic feasibility. This is because the subsidized amount cannot be depreciated. Since the depreciation acts as a buffer against tax liability due to savings (in the same way as a deduction for personal income tax), not having the subsidized amount to depreciate is a substantial disadvantage. The incentives tend to become more powerful for larger investments. Shortening the depreciable life of the equipment increases the depreciation in earlier years, thereby lowering the tax liability. However, shortening the equipment life from five to two years has a limited effect on the project economic characteristics. Prior to the 1981 tax legislation, equipment life was twenty years, and shortening the life from that as a reference point would have had a dramatic effect on ROI.

Shortening the depreciable life has no effect on the payback period, since the time it takes the project to recoup the investment is longer than any of the depreciable lives. The timing advantage of the accelerated depreciation is thus lost.

Table 7
Annual Net Cash Flows for 100,000 lb/hr Boiler – Accelerated Depreciation Cases

	Depreciable Life (years)			
Year	*5*	*4*	*3*	*2*
0	-2950.0	-2950.0	-2950.0	-2950.0
1	-1830.0	-1830.0	-1830.0	-1830.0
2	213.1	322.9	487.5	844.2
3	706.6	843.8	1145.6	1804.2
4	729.4	894.1	1168.5	153.2
5	788.9	953.6	212.7	212.7
6	859.0	282.8	282.8	282.8
7	365.1	365.1	365.1	365.1
8	461.3	461.3	461.3	461.3
9	574.1	574.1	574.1	574.1
10	705.7	705.7	705.7	705.7
11	858.3	858.3	858.3	858.3
12	1035.2	1035.2	1035.2	1035.2
13	1240.0	1240.0	1240.0	1240.0
14	1476.8	1476.8	1476.8	1476.8
15	1750.3	1750.3	1750.3	1750.3
16	2325.3	2325.3	2325.3	2325.3

Table 8
Effect of Policy Incentives on Return on Investment (ROI).
The Incentives are Ranked in Order of Encouraging Effect.

	Boiler Capacity (1000 lb/hr)					
Incentive	*50*	*100*	*200 Percent ROI*	*300*	*400*	*500*
40 Percent Extra TC	16.4	20.3	22.2	21.9	22.6	23.1
50 Percent Subsidy	13.6	18.2	20.2	19.6	20.4	20.9
30 Percent Extra TC	13.8	17.7	19.5	19.1	19.8	20.2
40 Percent Subsidy	12.2	16.5	18.4	17.8	18.5	19.0
20 Percent Extra TC	11.7	15.5	17.2	16.8	17.4	17.9
30 Percent Subsidy	11.0	15.1	16.9	16.3	17.0	17.5
20 Percent Subsidy	10.0	14.0	15.7	15.1	15.8	16.2
10 Percent Extra TC	10.0	13.7	15.3	14.8	15.4	15.9
2 Year Life	9.2	13.1	14.8	14.2	14.9	15.3
10 Percent Subsidy	9.2	13.0	14.6	14.0	14.7	15.1
3 Year Life	8.9	12.7	14.4	13.8	14.4	14.9
4 Year Life	8.6	12.4	14.0	13.4	14.1	14.5
Base Case	8.4	12.1	13.7	13.1	13.7	14.2

COSTS AND BENEFITS OF INCREASED TAX CREDITS

Since the tax credit option produces a greater effect on return on investment, an investigation has been conducted to determine the overall effect of a program to reduce oil imports by providing tax credits. Taking the 200,000 lb/hr boiler as an example, the base case ROI is 13.5 percent. Assuming the minimum acceptable ROI is 17 percent, the least costly incentive that can be offered is an additional 20 percent energy tax credit. (See Table 8).

In order to calculate the cost to the federal government, the total number of boilers must be known. This is listed in Column 2 Table 9. The number of boilers in the 50,000-99,000 lb/hr range is the author's estimate. Assuming 25 percent of the boilers cannot be converted for practical or institutional reasons, Column 3 of Table 9 lists the number which can be converted, and Column 4, the cost per boiler of an additional 20 percent tax credit.

Multiplying the cost per boiler and the number of boilers per range and summing over all ranges, the total cost of the program would be $6 billion. The data from column 4 of Table 3, assuming these values apply to the entire boiler capacity interval, provide the energy displacement per boiler. Multiplying the number of boilers by the energy displacement per boiler in each size range and summing over all size ranges indicates that 2.74 Quad can be displaced to coal. Under the assumption of 65 percent natural gas and 35 percent oil, this means that 1.78 Quad of natural gas and 0.96 Quad of oil can be displaced to coal. Using heating values of 1000 Btu/cubic foot gas and 150,000 Btu/gallon oil, the actual displacements become 1.78×10^{12} cubic feet of gas and 6.4×10^{9} gallons of fuel oil annually.

Since the United States imported approximately $1{,}737 \times 10^{6}$ barrels of oil in 1980, the proposed program would reduce oil imports by an equivalent of

Table 9
Boiler Conversion Data

Boiler Capacity (1000 lb/hr)	*Number of Oil- and Gas Fired Boilers*	*Number of Boilers Convertible*	*Cost per Boiler (1000 $)*
50-99	1500	1125	730
100-149	1190	892	1120
150-249	1068	801	2090
250-349	400	300	3592
350-449	182	136	4616
450+	192	144	5584

8.7 percent [3]. At an October 1981 cost of $35/barrel, this represents not importing $5.3 billion worth of oil annually.

The displacement of 2.74 Quad of natural gas and oil to coal means that an additional 110 million tons of coal must be mined, transported, and burned. Since the United States produced 776 million tons of coal in 1979, this implies a 14 percent increase in coal use due to this program [3]. Further study is needed to determine the ability of the mining and transportation sectors to meet this demand.

CONCLUSIONS

One of the most powerful concepts in reducing oil imports is converting industrial boilers to burn coal using fluidized bed combustion technology. This method employs a sorbent (limestone or dolomite) which is added with coal to a fluidized bed and reacts with the sulfur in the coal to lower SO_2 emissions. However, this technology is presently not economically feasible due to high capital costs.

An interactive computerized cash flow model was developed in this study to determine the payback and return on investment for a given coal conversion project. Due to installation economy of scale, projects became more feasible as they became larger. Savings increase linearly with boiler capacity and the capital investment increases at a rate less than the savings. This effect causes the base case return on investment to increase with boiler capacity. Similarly, the incentives become more powerful for larger investments.

Tax credits are more influential in determining economic feasibility than are subsidies. This is because the subsidized amount cannot be depreciated. Not having the subsidized amount to depreciate is a substantial disadvantage.

Shortening the depreciable life of the equipment increases the depreciation in earlier years, thereby lowering the tax liability. However, shortening the equipment life from five years to two years has a very limited effect on the project economic characteristics.

Shortening the depreciable life has no effect on the payback period, since the time it takes for the project to recoup the investment is longer than any of the depreciable lives. The timing advantage of the accelerated depreciation is thus lost.

The least costly policy incentive which increases the return on investment above as assumed 17 percent minimum acceptable return on investment is an additional 20 percent tax credit. If the federal government were to offer an additional 20 percent tax credit, and 75 percent of the eligible boilers were converted to coal, oil imports could be reduced by an equivalent of 8.7 percent. Although the cost of the program is $6 billion, the imported oil savings is valued at $5.3 billion in October 1981 costs.

REFERENCES

1. J.D. Keenan and M. Maguire, Cost Model of Industrial Fluidized Bed Boilers, to appear *Proc. ASCE, Journal of Energy Engineering,* 1983.
2. Exxon Research and Engineering Company, *Application of Fluidized Bed Technology to Industrial Boilers,* prepared for ERDA by Exxon. EPA-600/7-77-011, 1977.
3. Congressional Research Service, *Energy Factbook*, prepared by Congressional Research Service of the Library of Congress. U.S. Government Printing Office, Washington, D.C., 1980.

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