An Economic Feasibility Study of Crop

Residues as an Auxilary Fuel Source

for Iowa's Coal-Fired Power Plants

by

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Abstract

The rising costs of fossil fuel have sparked interest in crop
residues as an alternate, renewable energy source. The costs of crop
residue for direct combustion in power plants are estimated in 1975
prices in order to evaluate the economic feasibility of this source of
energy. The costs are estimated for the following three stages in the
crop residue production process: farm level production costs, transpor-
tation costs, and processing and handling costs at the energy recovery
level. These costs are then incorporated into an Iowa agricultural
linear programming model. The programming model, for Iowa agriculture,
includes costs and demands of an electric utility sector.

The model, including Iowa crop production activities, is used to
make solutions for several alternative scenarios. One is a base
solution for comparison of the other alternatives. Energy prices are
increased in another solution. Finally, one solution constrains sulfur.
Under each of these scenarios crop residue replaces coal at the levels
of 20, 40, and 60 percent of the 1975 BTU's consumed.

Comparison of the various scenarios with the Base Run allows
comparison of agricultural production costs, energy use, and net
income. Estimated, also, are the direct and indirect costs of crop
residues for each of the forementioned scenarios. Finally, net benefit
of using crops residues is derived.

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The United States is a nation rich in domestic energy resources
yet large quantities of energy are imported. Exxon Corporation
[Anonymous, 1978] examined the world's energy situation and concluded
that a significant shift in the shares of energy supplied by various
fuels could occur by 1990. In addition, they concurred with the
Project Independence Task Force that synthetic fuel, solar, and other
energy forms could be the base for a rapid rate of expansion. It is
a facet of this area, a solar based energy supply, this study examines.

Crops capture solar energy, a flow resource, and combines the
energy with other elements such as plant nutrients and water inherent
in the soil, and carbon dioxide from the air. These constituents
combine to form grains, fruits, and fibers. The past and present
purpose of U.S. agriculture is to provide food and fiber desired by
consumers. A future purpose of U.S. agriculture may be, in addition
to supplying food and fiber, to provide energy. Significant amounts
of energy from U.S. agriculture in excess of out basic food and fiber
requirements and other needs, may come from energy crops, agricultural
by-products, crop residues, and animal wastes.

These products and by-products of the future agricultural production process can be termed biomass. Biomass consists of carbon to carbon bonds. It is from these bonds that energy originates and may be an answer to providing crucial energy in the future.

The primary fuel stock considered in this study is crop residue which consists principally of the stalks and leaves of crops such as corn grown for grain. Presently, some of these residues are removed or used in situe for livestock feed. For the most part, crop residues are incorporated into the soil. For every 16 kilocalories (kcal) produced through the capturing of energy by plants, 3.9 kcal are inherent in the residues left after harvesting [Nelson, Burrows, and Stickler, 1975]. These materials when left in the field are useful for soil conservation, but they also have some future potential for use as a renewable energy source.

Objectives

This study examines the direct combustion process of crop residue. More specifically, the study examines the economic feasibility of using crop residues in Iowa's electrical generating power plants. A maximizing linear programming model representing Iowa is used to access this economic feasibility. The economic feasibility is evaluated with three different possible future scenarios: the Base, Increased Energy prices, and Sulfur Constrained. Under each of these scenarios, crop residues are substituted for 0, 20, 40 and 60 percent levels of coal consumed in 1975 by Iowa's power plants. The Base assumes 1975 costs

and 1970-1975 average yields, production prices, and 1975 sulfur emission regulations. The other two scenarios assume double 1975 retail energy prices. The Sulfur Constrained scenario assumes the projected environmental sulfur emission standard in addition to the increased energy prices.

Study Area

Iowa is selected as a representative study area because Iowa has a high density of crop residues, and the electric utilities are dispersed. The state of Iowa is divided into 12 agricultural producing regions consistent with Iowa's soil conservancy districts, and 19 utility sectors (Figure 1). Small utilities are not incorporated into the model as the costs of using residue for these power plants are prohibitive.

The Model

The linear programming model used in this study can be divided into three separate sectors: the crop production sector, the crop residue sector, and the power plant sector. These sectors are interrelated through land use and/or crop residue transfer constraints. The model maximizes the net agricultural return to Iowa subject to a set of primary constraints. A more detailed discription of the model is given in English, Short and Heady forthcoming.

The objective function includes the cost of agricultural production, the gross returns of endogenous crops, and the cost of

coal for electrical generation to power plants located in Iowa. The agricultural returns can be derived by adding to the objective function's value the cost of coal to Iowa's power plants. Costs of producing agricultural commodities included in the model are labor, machinery, pesticides, energy, and fertilizers. The objective function is subject to predetermined livestock demands, availability of land resources in five land management classes, and 1975 fuel and sulfur requirements by the power plants.

All three subsectors within the model consume energy. The agricultural sector uses energy in the production process of crops and the harvesting of crops. Energy inherent in the fertilizers, pesticides, and herbicides is also defined. The use of coal and/or crop residues by the power plant requires diesel fuel for transportation. The amount of energy by fuel type is quantified for crop residue processing and coal benefication. Finally power plants use coal for electrical generation, 118, 94, 71, and 47 trillion BTU's for 0, 20, 40 and 60 percent coal replacement.

Crop Residue Costs

The costs of crop residues are estimated for three stages of crop residue production and energy conversion -- farm level, transportation, and processing and handling at the power plant (Table 1). Costs included in the farm level stage are harvesting and agronomic costs with initial storage of the residues assumed on the farm.

Transportation costs are estimated as a function of unit transportation costs and the size and shape of the collection area which depend on the location and size of the power plant. Processing and handling costs at the power plant includes capital investment in buildings and equipment, wages, and costs for operating and maintaining the system. The processing and handling system, as perceived, requires the reduction of crop residues to a homogeneous size and short-term storage of the residues. Processing and handling costs are subject to considerable economics of size so these also depend on the power plant.

Results

The use of crop residues affects crop production, energy consumed, nitrogen demanded, agricultural production cost and net income. The impacts of utilizing crop residues on Iowa's agricultural sector are first examined, then the economic viability of using crop residues are determined by examining the costs and benefits of residue use in comparison to coal use.

Impacts on Iowa's Agricultural Sector

The total value of endogenous crops sold exceeds three billion dollars in all scenarios examined. With both Increased Energy Prices and Sulfur Constrained, as the percentage of crop residues increased to from 0 to 60 percent, the gross value of crops produced decreases from 1.78 to 2.92 percent respectively (Table 2). Thus, using crop residues causes a shift in most cases to a lower valued crop at 1970-1975

average prices. This shift for the most part is due to a shift from soybean production to corn production, a higher residue yielding crop.

Total changes in energy use do not vary significantly when comparing one scenerio with another. In examining the energy used when residues are utilized, however, the quantity of energy used in supplying the fuel is less than that quantity saved through coal replacement (Table 3). Thus be using crop residues, energy used from traditional sources is less then that when only coal is used.

Nitrogen use decreases between 8.5 to 9 percent at all levels of crop residue use as energy price increases. The harvesting of residues results in additional nitrogen requirements of 10, 20 and 30 thousand tons to replace the nitrogen lost. In addition, more nitrogen is used in crop production corresponding to the change in cropping patterns previously mentioned. More nitrogen intensive rotations are required as residues demanded increases.

Several components must be examined before net income is derived. As previously mentioned, the objective function includes not only the costs and returns attributed to agricultural activities, but also the at the mine, transportation, and handling costs of coal used by Iowa's power plants, and the transportation and processing costs of crop residues. When these components are added to the objective function, net income to the crop and crop residue producing portion of the agriculture sector is derived. Net income then is the monetary return to Iowa farmers, but does not reflect any cost for land,

management or the risk aspects of agriculture (Table 4). When
examining the Base scenario, the results indicate that by supplying
crop residues a decrease in net income of 1.36, 2.81 and 4.17 percent
occurs at the 20, 40 and 60 percent levels of the Base Run.[a]

As energy prices increase and sulfur levels further restricted,
the decrease in net income is much less. This loss in net income is
primarily due to the agronomic and harvestings costs borne by the
farmer. An additional cost is incurred due to the shifting crop
patterns.

Economic Feasibility of Crop Residues

The costs of crop residues include both direct and indirect costs
(Table 5). The direct costs are those attributed to harvesting,
transporting, and processing the residues plus the agronomic costs of
nutrient replacement. The indirect costs include the costs incurred
due to cropping pattern shifts caused when residues are supplied by
the farmers. Other costs of crop residues such as organic matter
maintenance and decreased productivity over the long run, and benefits
such as reduced pesticides, and reduced fall plowing are not incorporated
within the scope of the study. These components would affect the in-
direct costs of crop residue. Another study indicated that if soil

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[a]
It must be remembered that farmers are not being compensated for
supplying the residues. While the costs of residues do incorporate a
labor cost and a return on capital used, in actual practice, farmers
would require a return of this amount of providing the residues.

erosion is maintained at the base level, it would cost the farmer

an additional $0.11 per ton of residue produced at the 60 percent

replacement level. At other levels, 20 and 40 percent, the cost is

about $0.01 per ton. This is due in part to a shift in management

practices so that yield would be maintained in the long run.

On a BTU basis alone, the use of crop residues becomes economi-

cally feasible only when coal and other energy prices double (Table

5). Even at this point, the feasibility of residues is marginal.

If the benefit of the sulfur contribution is credited, however, the

doubled coal and energy price scenario indicates crop residues are

indeed feasible with a new benefit of $0.24 and $0.11 per MMBTU for

the 20 and 60 percent levels respectively. When sulfur is constrained,

this added benefit increases to $0.36 and $0.49 per MMBTU.

The costs incurred by farmers and the power plant operators can

be seen in Figure 2. These results are consistant over all the

scenarios though the percentages differ slightly due to increased

energy costs. From the figure, one can see that farmers share of the

costs increase as the percent of residue used increases. This in

primarily do to the fixed costs inherent in the power plant's process-

ing facility. It should be remembered however, that the power plant

does have a large capital investment in the processing facility.

The above analysis does not include any costs required for risk.

In addition, the designed processing plant may not be optimum in nature.

As previously mentioned, additional benefits received by farmers for

their residue harvesting efforts, such as reduced fall plowing and reduced need for pesticides and herbicides, are not included in the analysis. These benefits would result in the power plant paying less to the farmers then otherwise indicated.

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Table 1. Total costs of crop residues to the power plant

Cost Stage	Processing plant capacity in tons per year				
	24,800	74,400	148,800	223,200	297,600
	. . . . (dollars per ton) . . . .
Farm level	11.68	11.68	11.68	11.68	11.68
Transportation	.79	.91	.99	1.05	1.11
Processing and Handling	12.66	6.11	4.28	3.63	3.22
Total	25.13	18.70	16.95	16.36	16.01

Table 2. Gross value of crops marketed and percent changes between and within the scenarios

Percent of Residues Demanded	Value of Crops Marketed for:		
	Base	Increased Energy Prices	Sulfur Constrained
		(percent)	(percent)
	. . . .(Million dollars) . . . .
Gross Value for:			
0	3,461.5	3,399.9	3,399.9
20	3,467.4	3,404.6	3,404.6
40	3,475.1	3,383.7	3,383.7
60	3.483.3	3,381.6	3,381.6
Changes from Base Within Each Scenario:	. . . .(percent) . . . .
20	0.17[a]	0.14	0.14
40	0.39	−0.48	−0.48
60	0.63	−0.54	−0.535

[a]Determined by deriving the percent change between the Base run at 0 percent residue use and the 20 percent residue use $1 - \frac{3467.4}{3461.5}$.

Table 3. Total energy use by type of energy

Scenerio	Coal	Diesel	Natural Gas	Electricity	LPG	Total
			. . . . (Trillion BTU's)			
Base:						
0	118	41.3	35.0	1.3	13.3	208.9
20	94	42.2	36.0	1.5	13.4	187.1
40	71	43.7	37.0	1.7	13.6	167.0
60	47	46.0	37.9	1.8	13.7	146.4
Increased Energy Prices and Sulfur Constrained:						
0	118	40.8	31.9	1.2	12.2	204.3
20	94	41.6	32.9	1.4	12.4	182.3
40	71	43.3	34.0	1.6	12.6	162.5
60	47	45.5	34.9	1.7	12.7	141.8

Table 4. Values for the objective function, coal cost, transporting and processing of crop residues, and net income, by scenario

Scenerio	Value for the:			
	Objective function	Coal Cost	Transporting and Processing of Residues	Net Income
	. . . . (Million dollars).			
Base				
0	1,215.1	99.7	0	1,314.8
20	1,208.3	79.0	9.5	1,296.9
40	1,202.7	58.5	16.6	1,277.8
60	1,202.0	38.1	19.9	1,260.0
Percent Change from Base for:	. . . . (percent)			
Increased Energy Prices				
0	−19.8	157.3	0	−14.0
20	−19.5	+157.8	121.8	−14.5
40	−19.3	+158.5	137.9	−15.0
60	−19.0	+160.9	156.8	−15.3
Sulfur Constrained				
0	−23.4	+201.3	0	−13.9
20	−22.2	+199.0	121.8	−14.5
40	−21.3	+200.8	137.9	−15.0
60	−20.1	+191.0	156.8	−15.5

Table 5. Economic feasibility of crop residues when evaluated on a
BTU basis alone.

Type of Fuel by Scenario	Percent BTU Replacement of Residue for Coal at:		
	20	40	60
	(dollars per MMBTU)		
Base:			
Coal	0.84	0.83	0.81
Crop Residue	1.14	1.12	0.90
Difference[a]	−0.30	−0.29	−0.09
Soil Constrained:			
Coal	0.84	0.83	0.81
Crop Residue	1.14	1.12	0.91
Difference[a]	−0.30	−0.29	−0.10
Double Energy Prices:			
Coal	1.30	1.30	1.28
Crop Residue	1.40	1.40	1.15
Difference[a]	−0.10	−0.10	+0.13
Double Coal and Energy Prices:			
Coal	1.65	1.65	1.58
Crop Residue	1.40	1.40	1.15
Difference[a]	+0.25	+0.25	+0.43
Sulfur Constrained:			
Coal	1.76	1.71	1.63
Crop Residue	1.40	1.40	1.15
Difference[a]	+0.36	+0.31	+0.48

[a]Negative quantities indicate lower costs for coal while positive
figures show lower costs for residues.
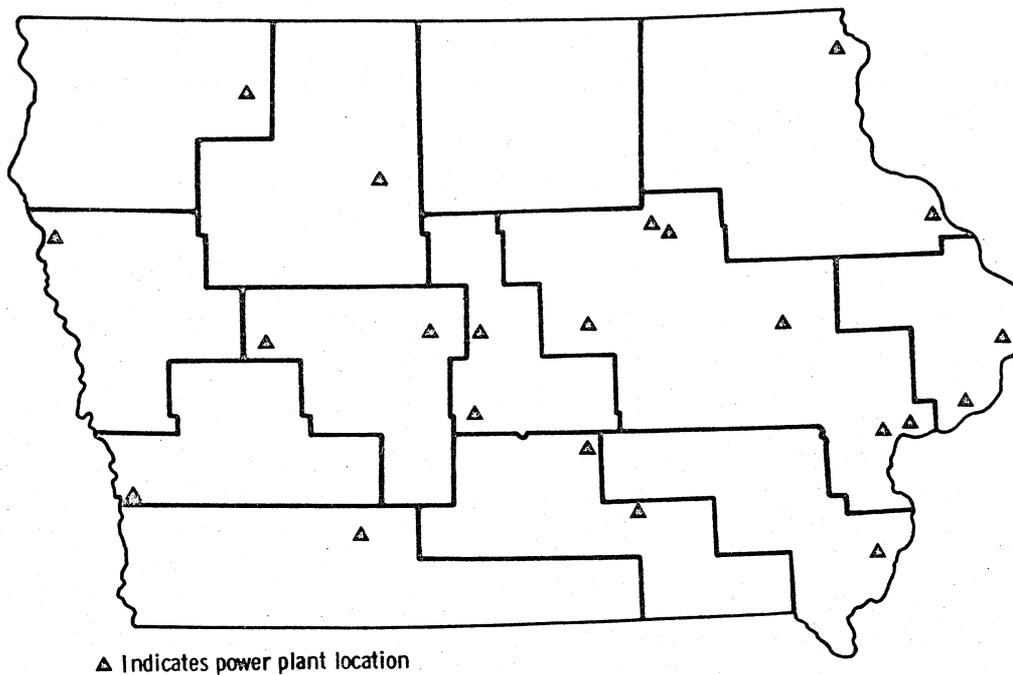
△ Indicates power plant location

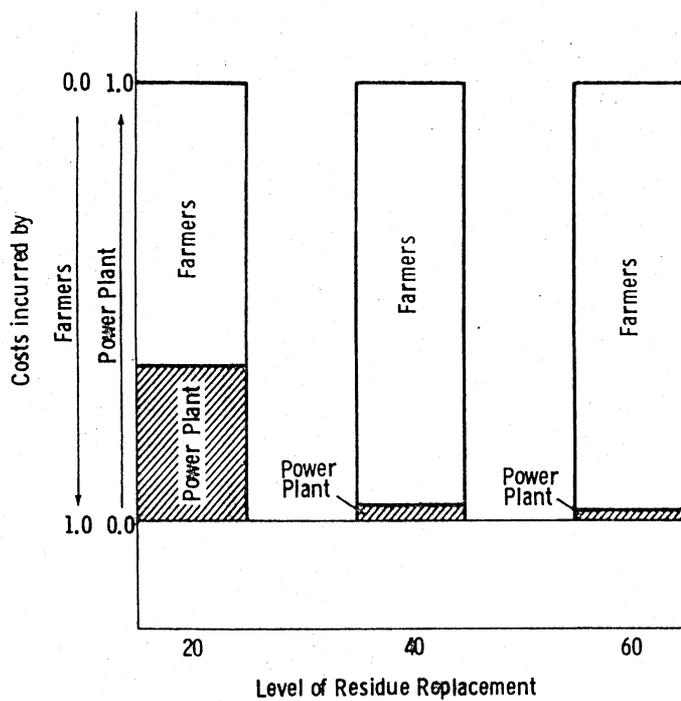Figure 1. Twelve agricultural regions and power plant location.

Figure 2. Proportion of costs incurred by the farmers and power plant operators.