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ECONOMIC POTENTIAL OF ON-FARM BIOMASS GASIFICATION FOR CORN DRYING

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SUMMARY: The economics of gasification using corn grain, cobs and stover as an energy substitute for LP gas is explored. The maximum amount a farmer could afford to invest in a gasification unit is calculated. When drying corn from 25.5 to 15.5 percent moisture, the maximum investment is 39¢ and 23¢ per U.S. No. 2 bushel for cobs and stover, respectively. A "negative" investment of 38¢ a bushel is computed when using grain as a fuel source.

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ECONOMIC POTENTIAL OF ON-FARM BIOMASS GASIFICATION FOR CORN DRYING

by

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Introduction and Objectives

Early harvesting of corn reduces the field losses associated with adverse weather and insects, and may enhance the price received at harvest time. In most areas of the country, early harvested corn must be dried if it is to be stored safely. The primary fuel sources for corn drying are liquid petroleum (LP) gas and natural gas, both of which burn cleanly and are utilized in directly fired systems. The returns to heated air drying are inversely proportional to the cost of LP and natural gas. Should the prices of these fuels become sufficiently high, substitute energy sources and technologies may develop. One such alternative is the gasification of crop residue.

Gasification is the process by which biomass is burned while controlling the air supply to the material. This process results in a combustible gas that may be ignited and mixed with ambient air to provide the heated air necessary for grain drying. The gasification process is not a new technology. Horsfield and Williams (1976), Horsfield (1977), Goss and Williams (1977) and Payne (1978) have traced the development of gasification. The first record of a gasification process was in 1839 when

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Bischaf patented a simple process for gasifying coke. Since that time many different types of cullulosic material have been used including rice hulls, olive pits, corn cobs, straw, walnut shells and animal manure.

Biomass gasification equipment is not currently being manufactured for use in crop drying. How much can manufacturers charge or farmers afford to pay for this equipment? The primary objective of this study was to answer this question by determining the break-even investment for biomass gasification equipment used in corn drying. For this study only corn grain, stover and cobs were evaluated as sources of energy, and storage of biomass and uses of the gasification equipment for purposes other than grain drying were not considered. The break-even investment was determined for one bushel of U.S. No. 2 corn defined as 56 pounds of grain at 15.5 percent moisture content.

A more in-depth discussion of the various topics presented in this paper may be found in Loewer (1980).

Availability of Biomass

The first consideration in using corn biomass for drying is to determine the quantity of material available and the relative proportions of the components. Buchele (1975), in reporting on the harvesting and utilization of corn stalks from Iowa farms, presented data from an earlier study by Ayres (1973). This information relates the dry matter distribution of the above ground plan parts as a function of grain moisture content and may be expressed in equation from as follows:

$$\text{Grain dry matter, } \% = 70.4 - 0.8*MC \quad (1)$$

$$\text{Cobs dry matter, } \% = 12.4 - 0.035*MC \quad (2)$$

$$\text{Stalks dry matter, } \% = 6.7 + 0.525*MC \quad (3)$$

$$\text{Leaves dry matter, } \% = -0.1 + 0.38*MC \quad (4)$$

$$\text{Husks dry matter, } \% = 10.4 - 0.065*MC \quad (5)$$

$$\text{Stover dry matter, } \% = 17.0 + 0.84*MC \quad (6)$$

where MC = percentage moisture content of the grain, wet basis.

For the purpose of this study, stover includes stalks, leaves and husks.

These equations may be used to compute the quantity of dry matter available as a function of yield and moisture content. Dry matter availability is of primary importance in determining energy availability.

Availability of Energy

The grass energy contents of corn grain, cobs, and stover are 9995,7961 and 7150 Btu per pound, respectively (Crampton and Harris 1969; Kajewski et al., 1977). These values must be adjusted downwardly to reflect latent heat differences, moisture content, gasification efficiency and drying efficiency. The percentage of the available biomass required for drying using one set of efficiency conditions is shown in Figure 1.

Economic Considerations

The gross return to using biomass as a source of energy for grain drying was defined as the cost of Liquified Petroleum (LP) gas required for the same drying operation. The expenses considered when using biomasss included harvesting and transportation costs, losses in nitrogen from the biomass, opportunity costs associated with alternative uses of the biomass, and operational expenses of the gasification equipment. The factors were all incorporated into a computer program called BIOMASS, and a sensitivity analysis was conducted using the set of base conditions given in Table 1. Several of these factors are discussed below:

Gasification Efficiency (Figure 2)

The efficiency of the gasification process has moderate economic implications. References cited previously indicate that gasification

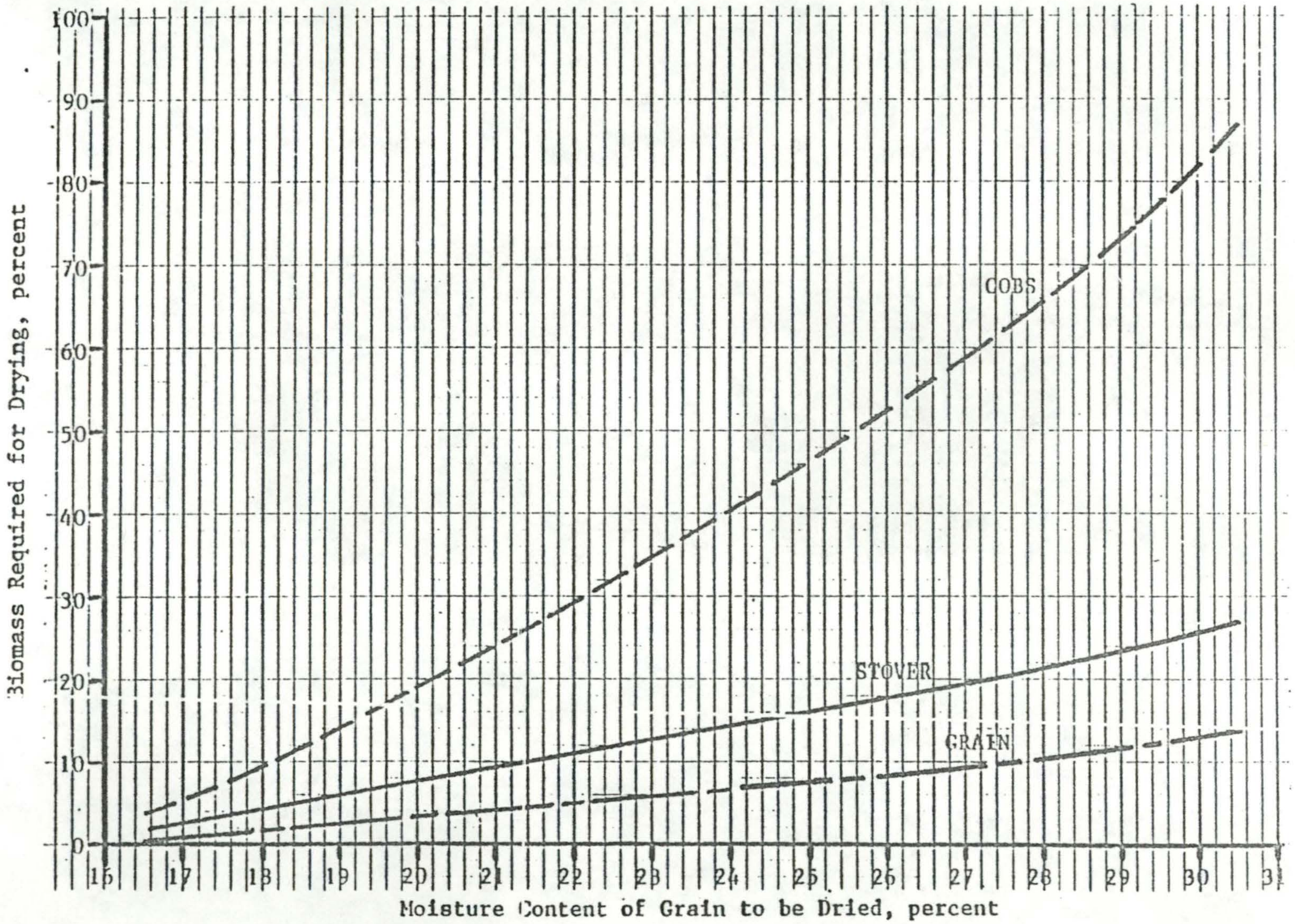

Figure 1. The percentage of the available biomass required to dry one bushel of U.S.No.2 wet grain (gasification efficiency = 60%; drying efficiency = 45%).

Table 1. Base values of inputs used in sensitivity analysis.

No.	Input Description	New Value
1	Initial grain moisture, percent	25.50
2	Desired final grain moisture, percent	15.50
3	Gross energy in grain, Btu/dry lb	9995.00
4	Gross energy in cobs, Btu/dry lb	7961.00
5	Gross energy in stover, Btu/dry lb	7150.00
6	Percent adjustment for bomb calorimeter	93.00
7	Percent efficiency of LP gas burner	80.00
8	Percent efficiency of drying process	45.00
9	Percent efficiency of gasification process	60.00
10	Nitrogen content in grain, percent of dry weight	1.60
11	Nitrogen content in cobs, percent of dry weight	0.45
12	Nitrogen content in stover, percent of dry weight	1.15
13	Heat of vaporization of water, Btu/lb	1060.00
14	Price of LP gas in year No. 1, ¢/gal	50.00
15	Constant change per year in LP gas price, ¢/gal	0.00
16	Change in LP gas price, percent from previous year	0.00
17	Price of nitrogen, ¢/lb	20.00
18	Percent/year for maintenance of gasification equipment based on purchase price	4.00
19	Annual interest rate, percent	15.00
20	Economic life of gasification equipment, years	10.00
21	Harvest-transport cost for grain, ¢/bu @ 56lb/bu	26.00
22	Harvest-transport cost for cobs in field, $/ton of wet material	5.00
23	Harvest-transport cost for stover in field, $/ton of wet material	10.00
24	Market value of grain at 15.5 percent moisture, $/bu	2.50
25	Market value of cobs in field, $/wet ton	0.00
26	Market value of stover in field, $/ wet ton	0.00
27	Retention rate of biomass nitrogen by soil, percent	80.00

Computed base break-even investment costs, ¢/dry bushel (U.S. No.2)	
Grain	-37.56
Cobs	38.88
Stover	23.49

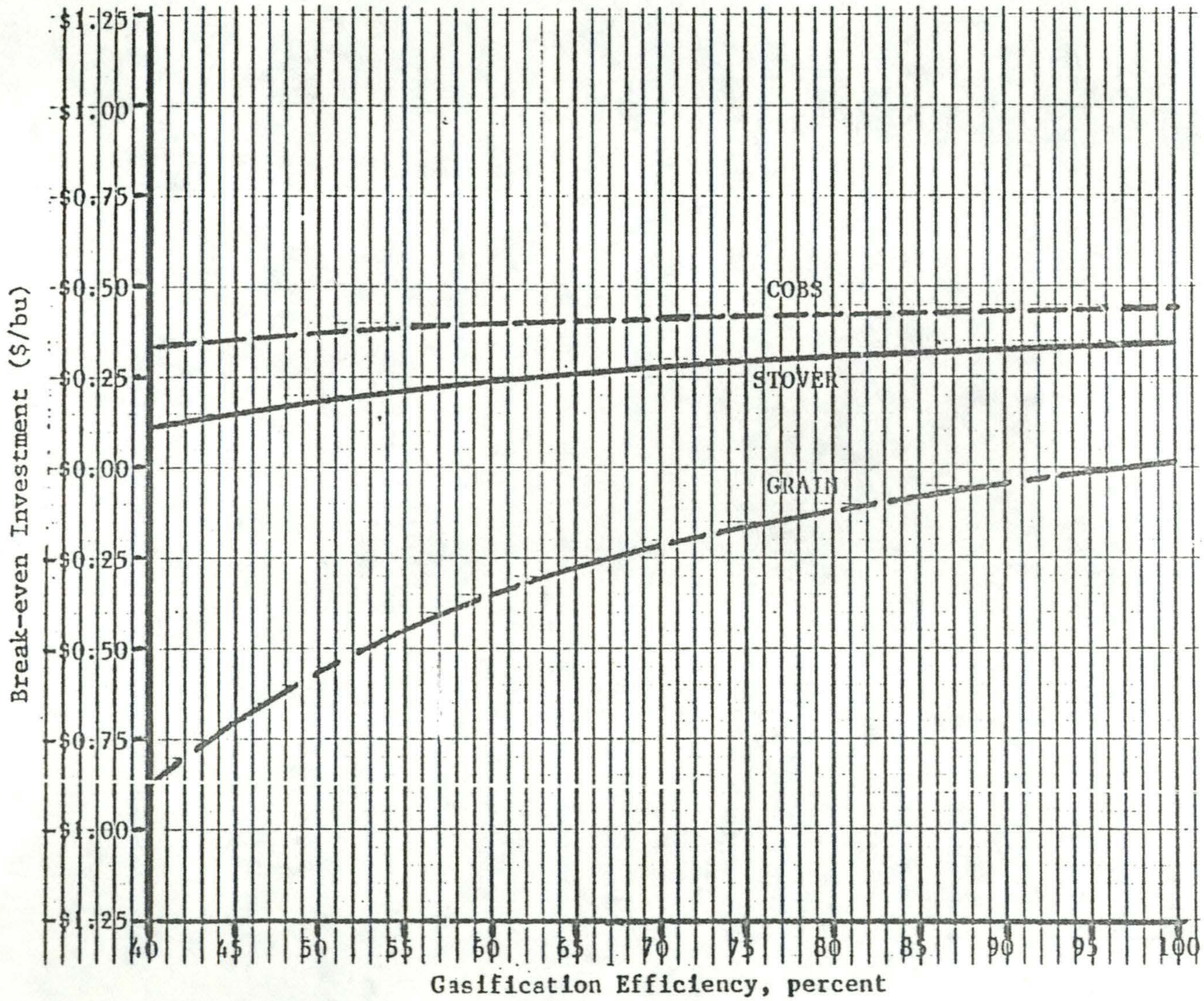

Figure 2. Effects of gasification efficiency on break-even investment per bushel of dry grain (U.S.No.2).

efficiency may reach 80 percent. An 80 percent efficiency, as compared to the base condition efficiency of 60 percent, increases the break-even investment for cobs, stover and grain by approximately 3, 7 and 14¢, respectively. The effect is more pronounced when using grain as a fuel source because it has a relatively high market value. Note, as the efficiency of the gasification process nears 100 percent, the break-even investment cost becomes positive for using grain as fuel.

Drying Efficiency (Figure 3)

As drying efficiency increases, the break-even investment cost narrows between using LP gas and biomass. The narrowing occurs because the relative quantities of fuel needed for drying increase with a decrease in drying efficiency. Thus, the relative break-even investments for using cobs or stover tend to decrease with an increase in drying efficiency. If the fuel source is grain, the break-even investment tends to increase.

Life of the Gasification Equipment (Figure 4)

As the economic life (assumed to be the same as the physical life) increases, the potential for using either cobs or stover increases at a moderate but diminishing rate, as would be expected. Likewise, the potential for using grain decreases. This actually says that for the base conditions selected, using grain for fuel to dry grain is a bad investment and the longer the life of the investment, the worse it becomes but at a decreasing rate.

Moisture Content of Grain to be Dried (Figure 5)

As initial mositure content increases, the break-even investment cost also increases when using cobs or stover. However, the rate of increase decreases and in fact becomes negative in the case of stover. The reduction in increase is because both cobs and stover collection costs are based on wet rather than dry material. Thus, the cost of

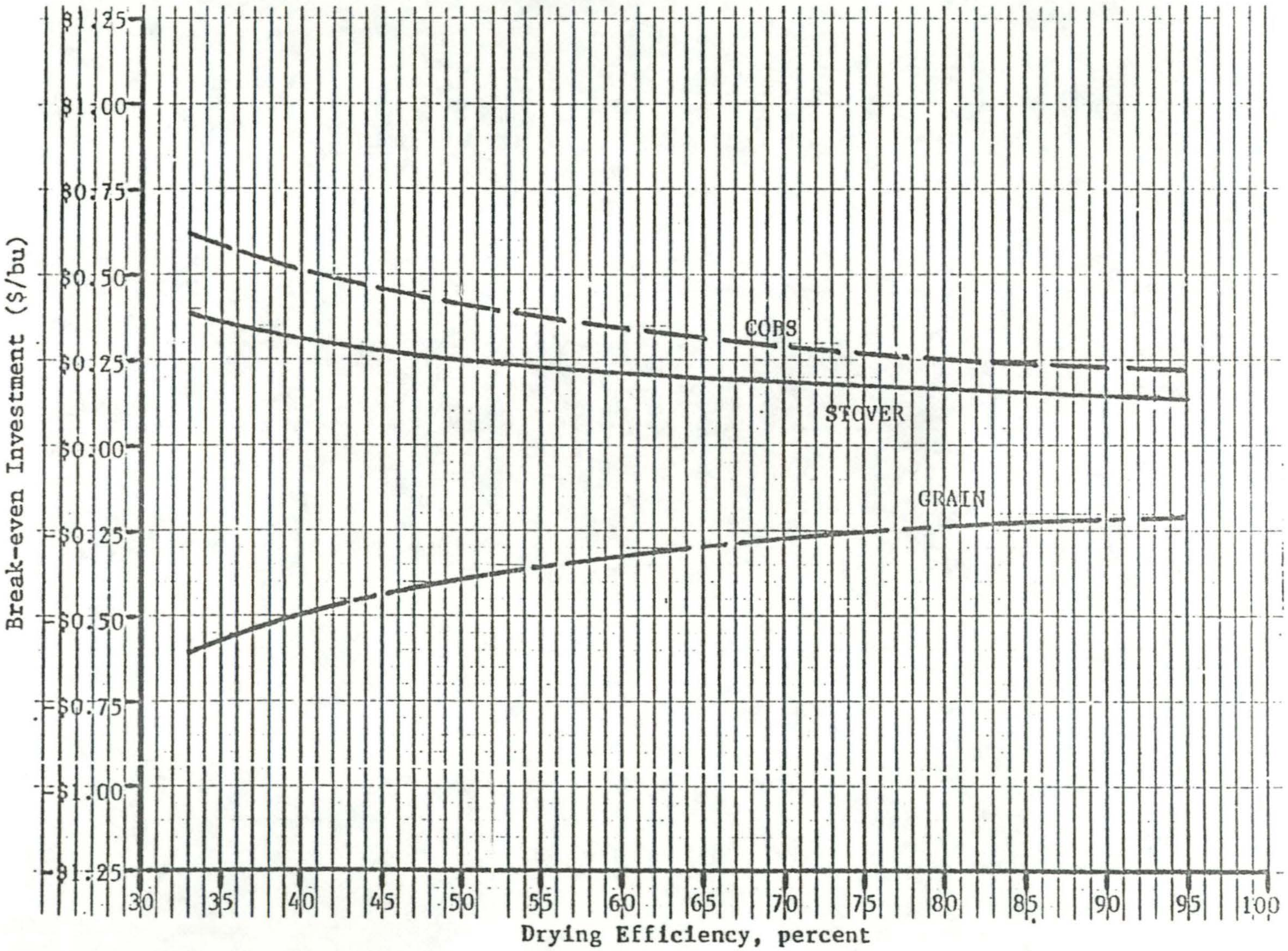

Figure 3. Effects of drying efficiency on break-even investment per bushel of dry grain (U.S.No.2).

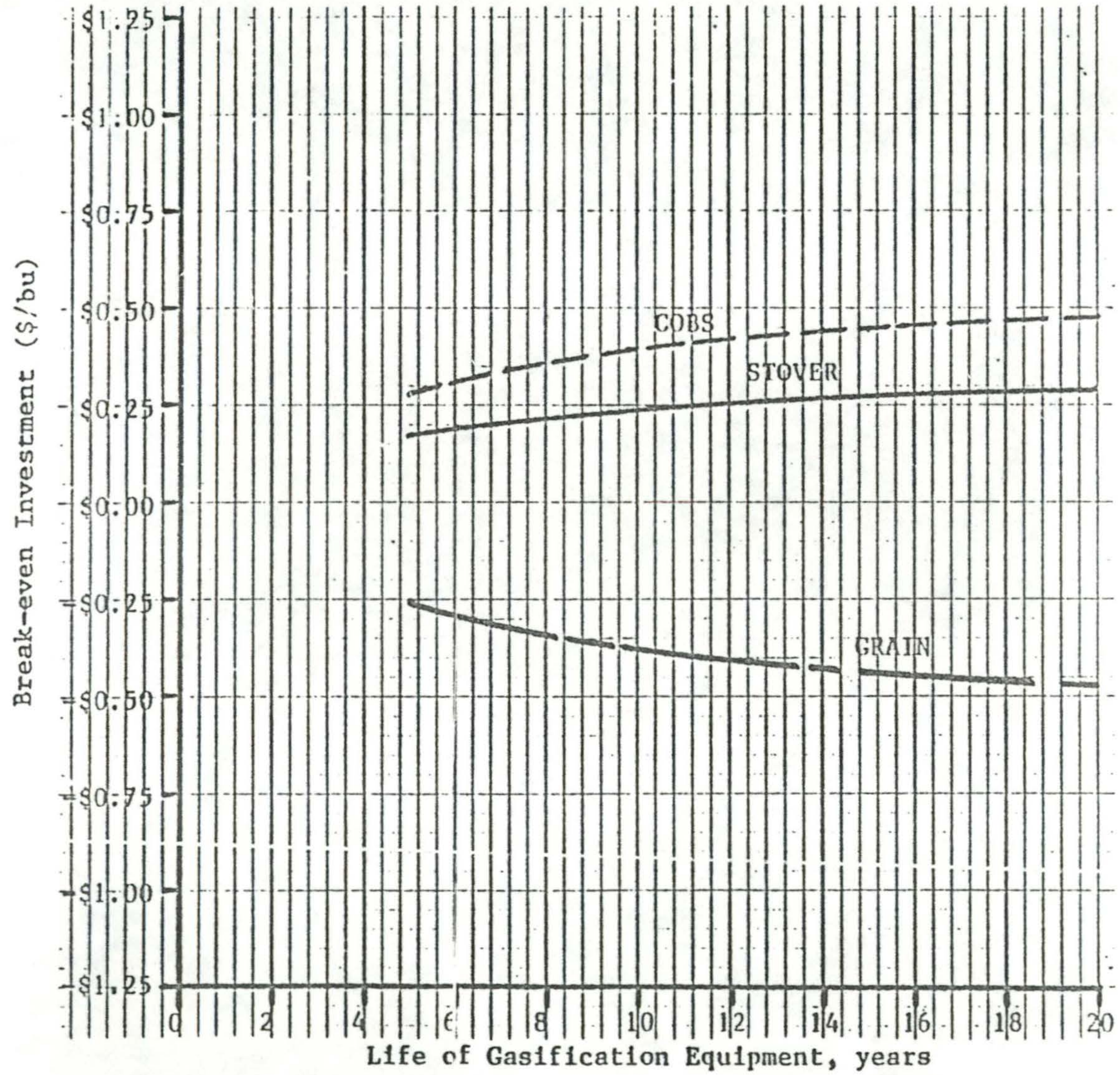

Figure 4. Effects of gasification equipment life on break-even investment per bushel of dry grain (U.S.No.2).

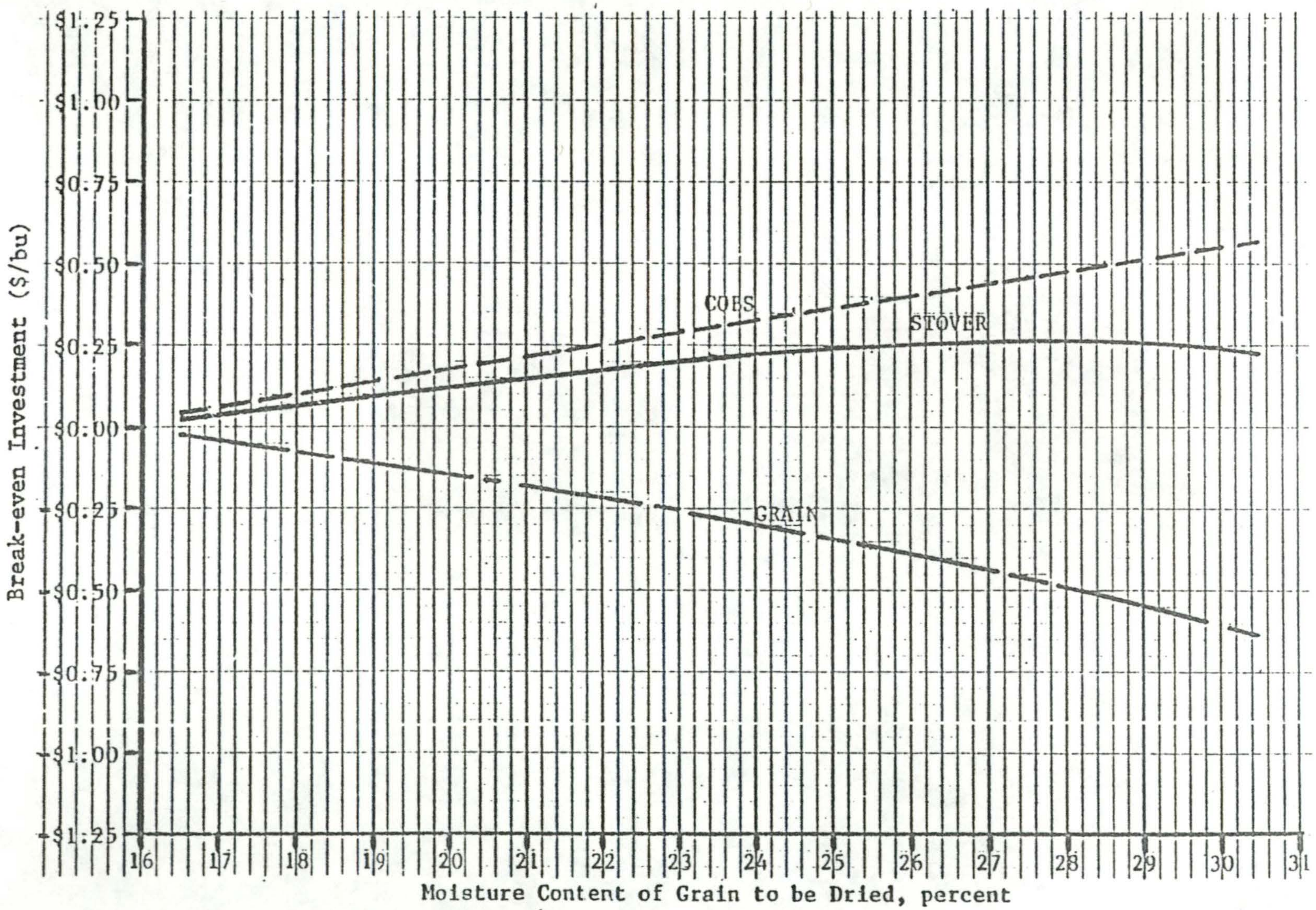

Figure 5. Effects of moisture content on break-even investment per bushel of dry grain (U.S.No.2).

collection (harvesting and transportation) increases faster than the savings associated with expanded use of LP gas at the higher moisture content. This effect is compounded when using grain as a fuel source in that it becomes a progressively poorer investment as moisture content increases. Note that drying efficiency is held constant over the entire range of moisture contents.

Interest Rate (Figure 6)

The break-even investment cost for cobs and stover decreases as the interest rate increases. However, the effects are less when moving from the base condition to higher values than when moving to lower values. In other words, future increases will have a relatively lower effect than past increases. In the case of grain, the higher interest rates reduce the return that must be obtained from other sources to subsidize the losses resulting from using grain as a fuel source.

Annual Operation and Maintenance (Figure 7)

Annual operation and maintenance are expressed as a single constant percentage of purchase price. It has no effect on situations where the expected return is negative as when using grain as a source of fuel. It has a moderate effect on break-even investment when using cobs and stover.

Harvesting Costs (Figures 8 and 9)

Large changes in the cost of harvesting grain have only a moderate effect on break-even investment cost. Certainly the changes are not sufficient to make grain a viable source of fuel. However, the costs of harvesting cobs and stover are very important factors to consider when computing the break-even investment cost of gasification equipment. In fact, harvesting costs of approximately \$20 and \$25 per ton of wet

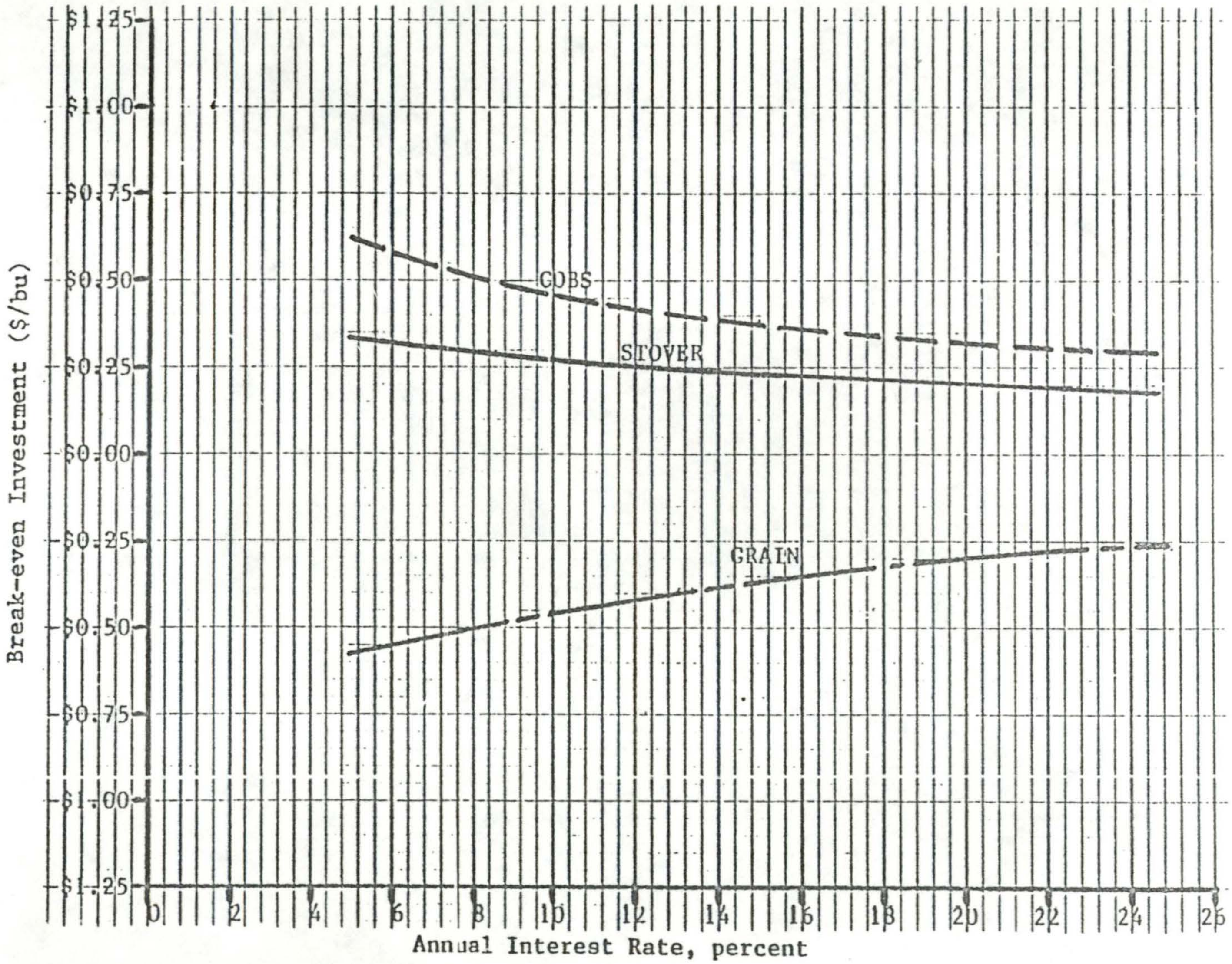

Figure 6. Effects of interest rate on break-even investment per bushel of dry grain (U.S.No.2).

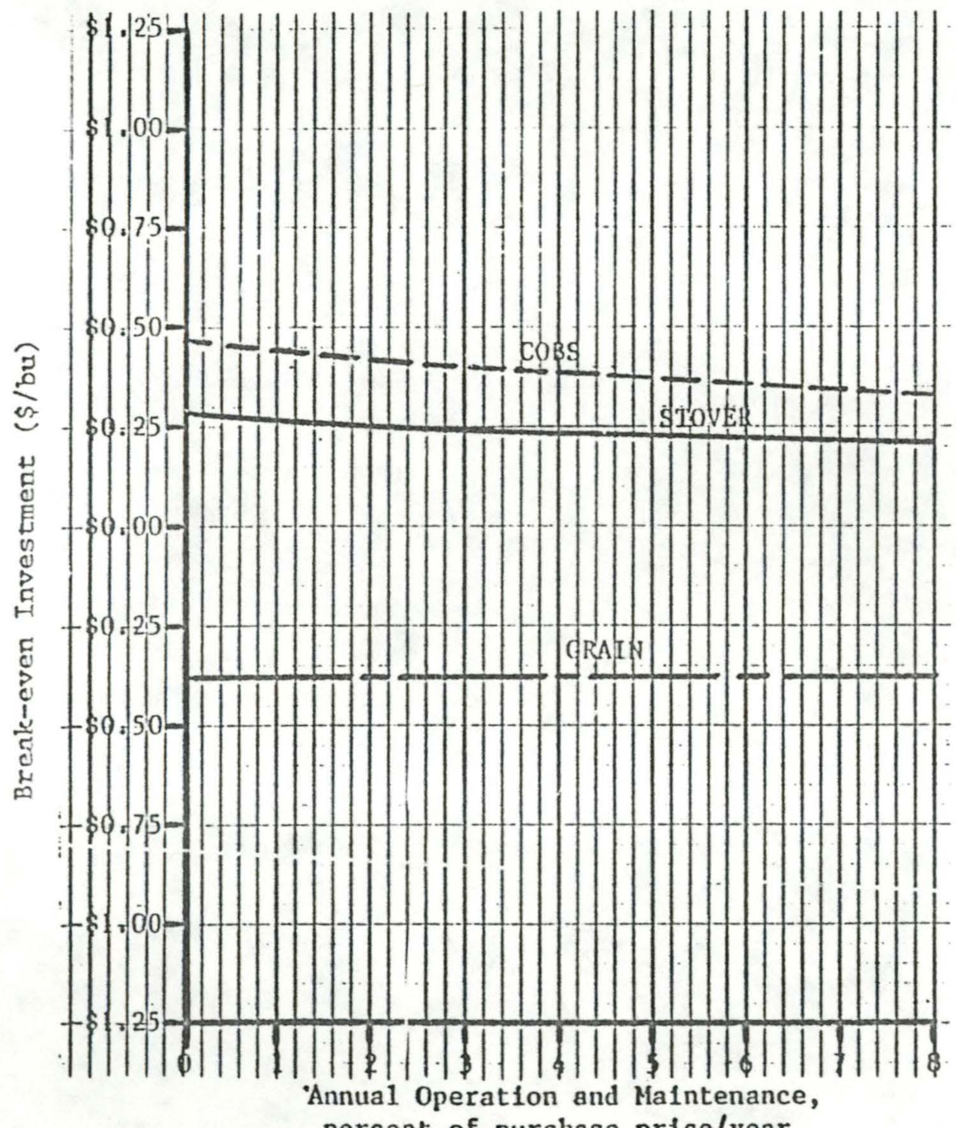

Figure 7. Effects of annual operation and maintenance on break-even investment per bushel of dry grain (U.S.No.2).

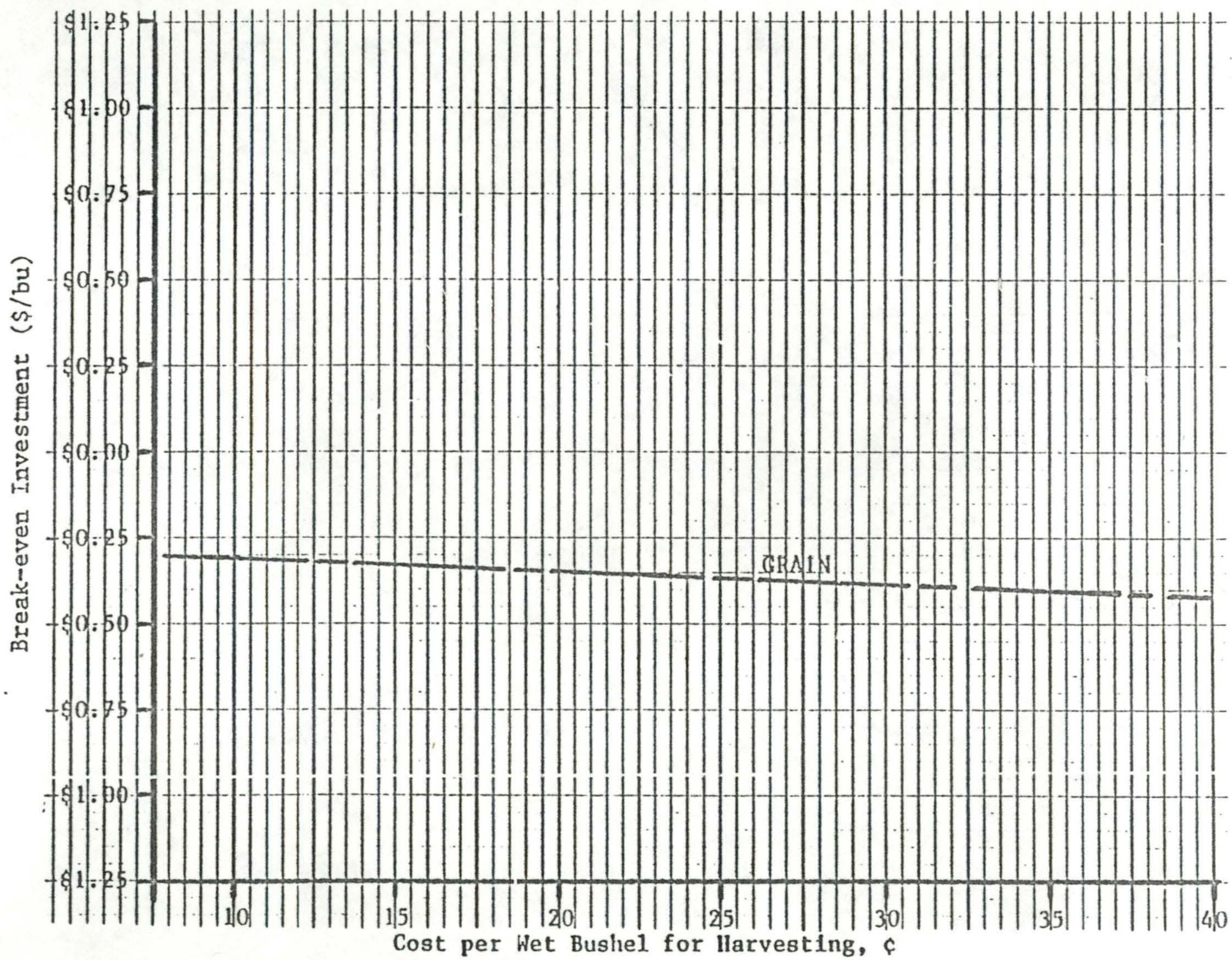

Figure 8. Effects of grain harvesting cost on break-even investment per bushel of dry grain when using grain as a fuel source (U.S.No.2).

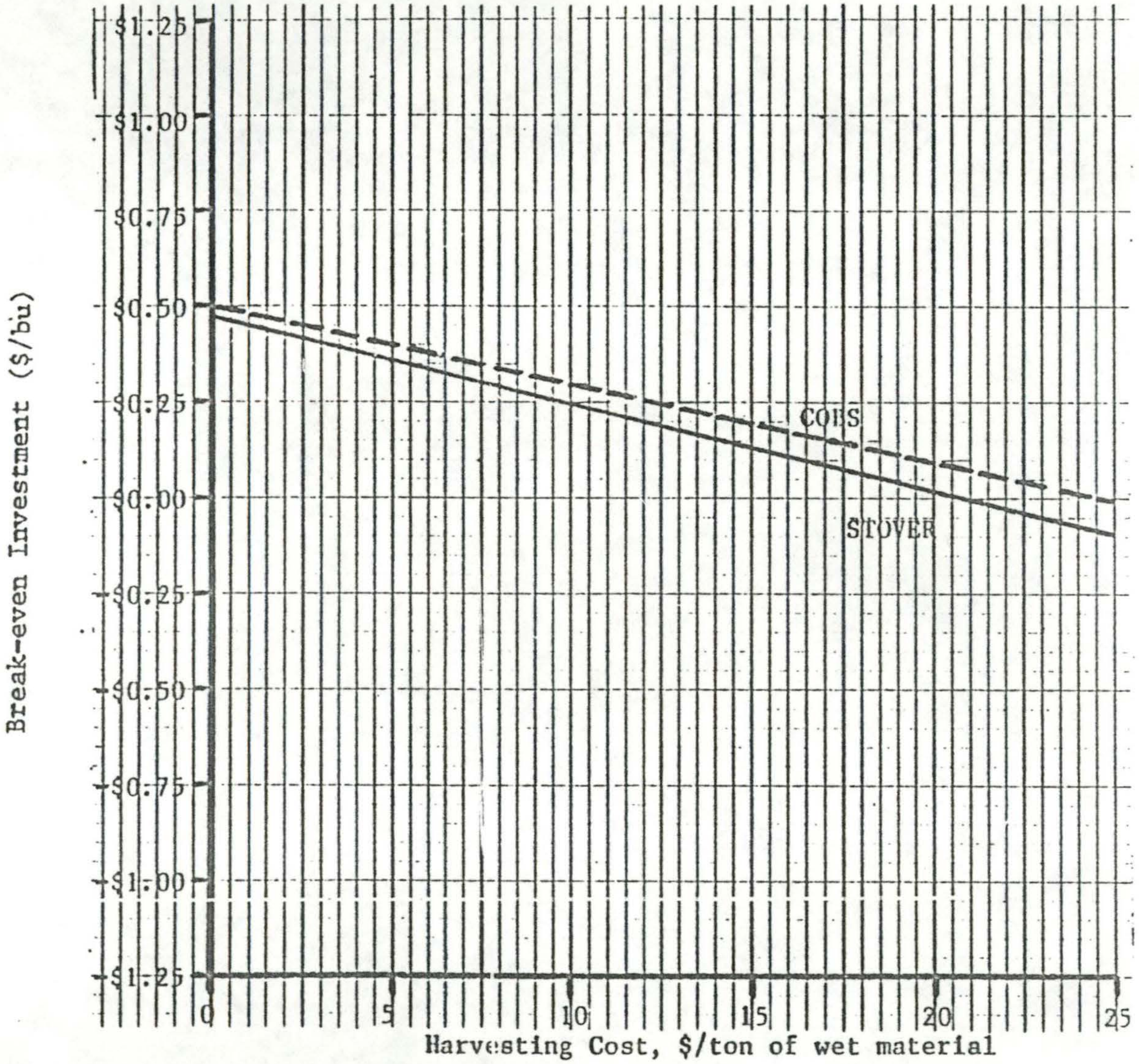

Figure 9. Effects of cob and stover harvesting costs on break-even investment per bushel of dry grain when using cobs and stover as a fuel source (U.S.No.2 grain).

material for stover and cobs, respectively, would result in a zero break-even investment.

Market Value of Biomass (Figures 10 and 11)

The primary reason that grain is not an economic source of fuel is its high opportunity cost; that is, grain can be sold and the resulting funds used to buy more energy in the form of LP gas than the grain itself contains. However, if grain were to sell for approximately $1.45 per bushel (15.5 percent moisture), it would be competeitive with LP gas as a fuel source for the values used in the base conditions.

The same logic applies to the use of cobs and stover for energy. The higher the market value, the less desirable they are as sources of energy, all other things being constant. The base conditions assume a market value of zero. However, a positive market value could reflect the equivalent worth of cobs or stover as animal feed or as a source of erosion control. For this analysis, a zero value for break-even investment would be obtained if the market value of cobs and stover were approximately $20 and $11 per ton of wet material, respectively.

Increases in LP Gas Price (Figures 12-14)

The break-even investment cost increases as the price of LP gas increases. Likewise, increases in the amount of drying amplifies the gains or losses in break-even investment. All increases in LP gas prices are considered real; that is, the price increase is relative to all other costs which are assumed to remain constant. This is especially important when considering that investment in capital goods occurs at one point in time with proposed returns being prorated over the life of the investment. This may result in losses during the early years of the investment only to be offset by gains in later years.

From the Figures 12-14, a real increase in LP gas prices of approximately 15 percent over each previous year would result in a postive break-even

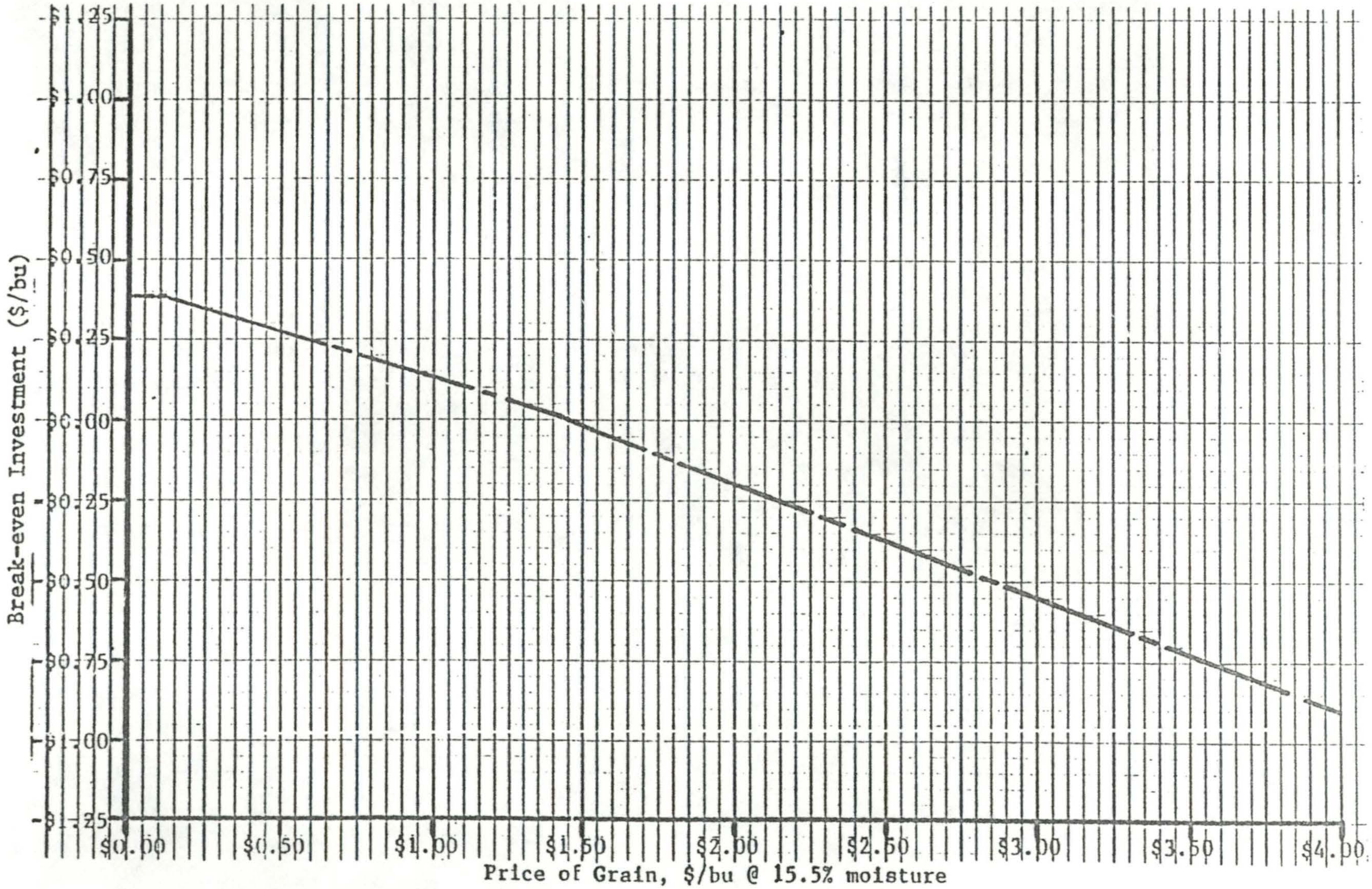

Figure 10. Effects of the market price of grain on break-even investment per bushel of dry grain when using grain as a fuel source (U.S.No.2 grain).

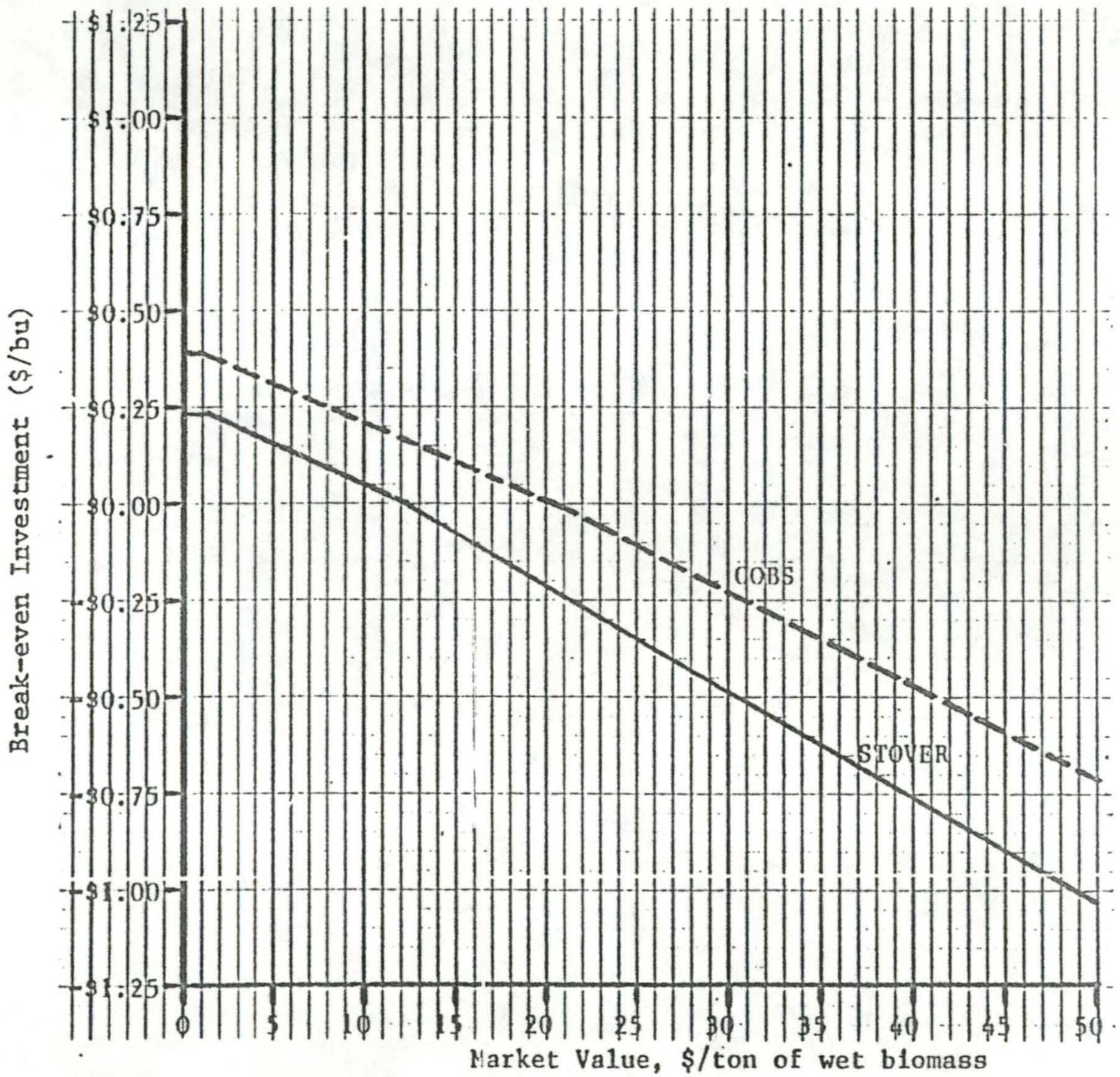

Figure 11. Effects of the cob and stover market value on break-even investment per bushel of dry grain when using cobs or stover as sources of fuel (U.S.No.2).

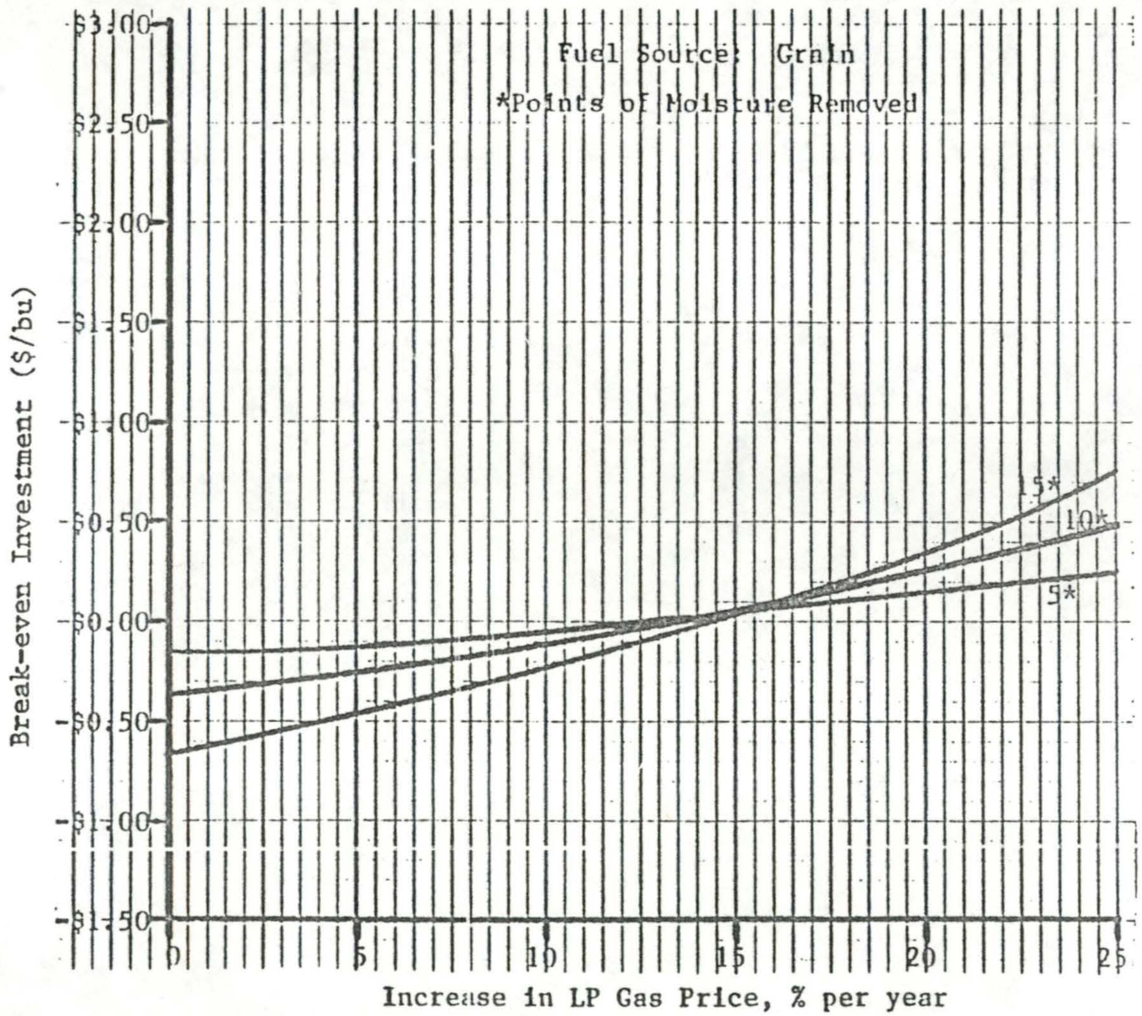

Figure 12. Effects of annual percentage increase in LP gas price on break-even investment per bushel of dry grain when using grain as a fuel source (U.S.No.2).

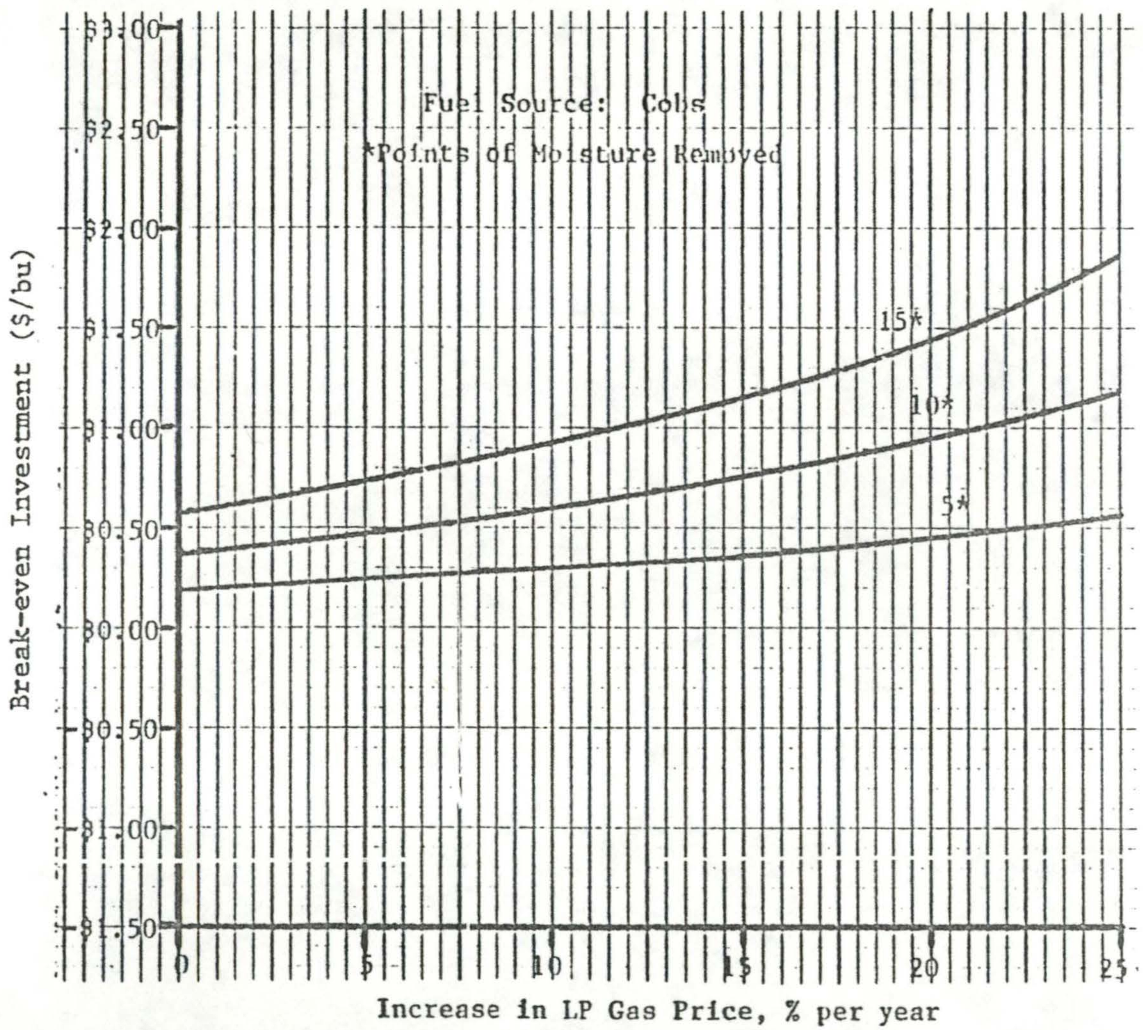

Figure 13. Effects of annual percentage increase in LP gas price on break-even investment per bushel of dry grain when using cobs as a fuel source (U.S.No.2).

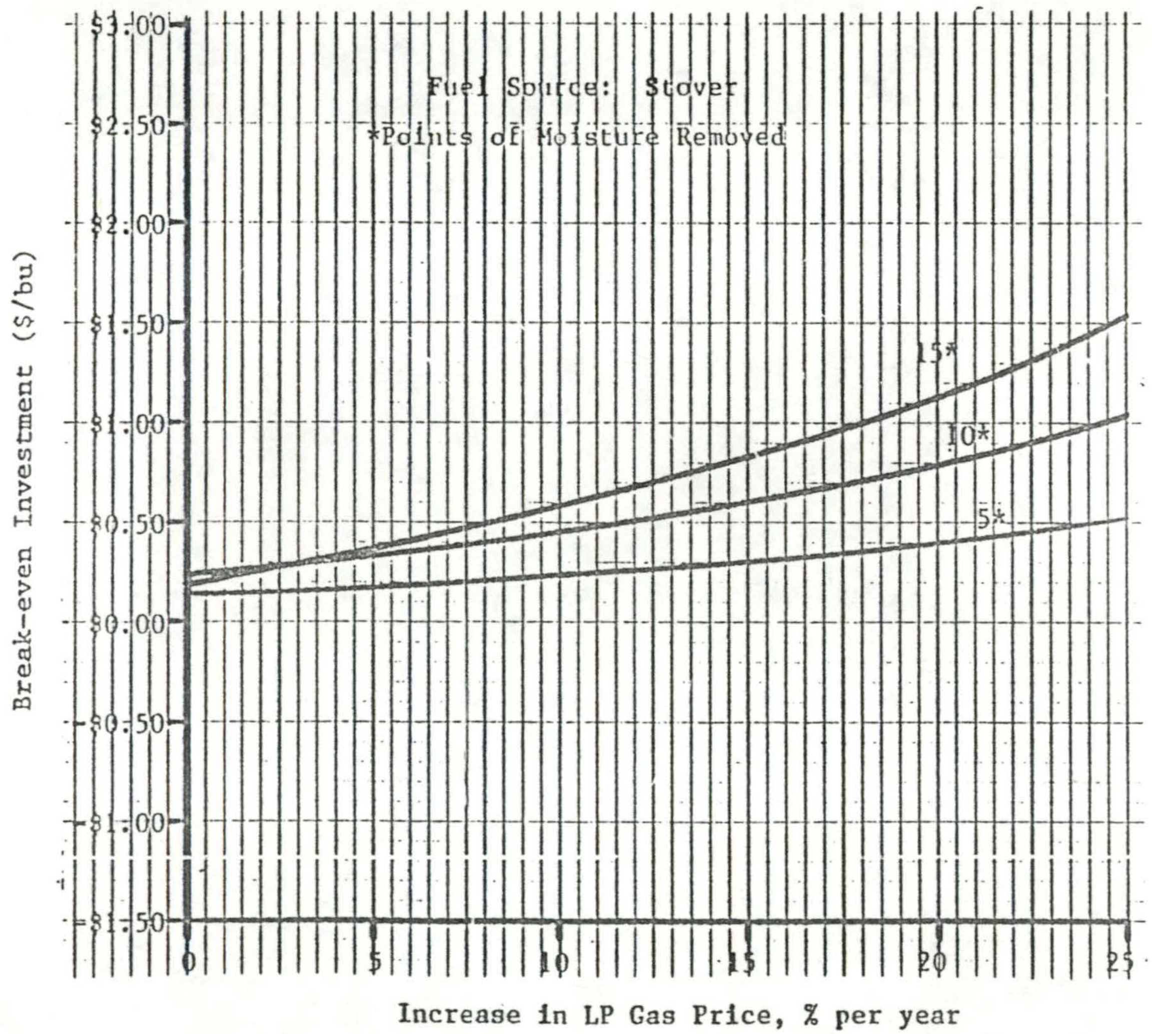

Figure 14. Effects of annual percentage increase in LP gas price on break-even investment per bushel of dry grain when using stover as a fuel source (U.S.No.2).

investment for grain as a fuel souce. It would also approximately double the break-even investment for cobs and stover for 10 points of moisture removal.

Constant real increases in LP gas prices would be equivalent to diminshing precentage increases. A constant real price increase of approximately 10 cents per year would result in positive break-even costs for grain as a fuel source. It would also approximately double the break-even investment for using cobs and stover at 10 points of moisture removal.

Conclusions

In this study, it has been shown that there is sufficient energy in the form of grain, cobs and stover so that the gasification process may be used to dry corn over the range of moisture content typical of harvest. Certain physical and economic parameters were determined to be essential in computing the economic feasibility of gasification. When using representative values for these factors, it was found that as much as 38.9¢ and 23.5¢ per U.S. No. 2 bushel dried could be invested in gasification equipment when using cobs and stover, respectively, as sources of energy for 10 points of moisture removal. However, grain itself could be used as a fuel source only if it were subsidized by the equivalent of 37.6¢ per bushel dried. Therefore, it would be extremely doubtful that grain would ever be economically competetive with cobs or stover as a source of fuel for grain drying.

The economic feasibility of using cobs and stover would be enhanced under the following conditions:

1. Increases in the efficiency of the gasification process.
2. Increases in the economic life of the gasification equipment.

3. Employment of high temperature drying methods that typically have lower drying efficiencies.

4. Increases in the quantity of moisture to be removed from the grain.

5. Reductions in the interest rate.

6. Reductions in the annual charge for operation and maintenance.

7. Reductions in harvesting costs.

8. Limited market value of cobs and stover.

9. Low prices of nitrogen.

10. Real increases in the price of LP gas.

The altering of these factors can have significant additive effects on the break-even investment cost. For example, if the base conditions given in Table 1 were altered to reflect the conditions shown in Table 2, the break-even investment would be \$1.59, \$2.63, and \$2.42 for grain, cobs, stover, respectively. This would represent a change in the base value of the break-even investment of approximately \$1.97, \$2.00 and \$2.18, respectively, for grain, cobs and stover.

It would appear that the use of cobs is the best gasification alternative. Cobs are presently passed through the combine and could be most easily gathered with existing grain harvesting machinery. This could be accomplished by either blending the cobs and the grain and separating them later, or by collecting the cobs as they exit the combine. It would also be possible to use ear corn harvesters and stationary shellers. In addition, cobs are more flowable than stover and thus offer advantages in terms of materials handling. Likewise, nitrogen removal is less with cobs than with stover, and stover is more effective in erosion control. The net effect of these advantages is that the break-even investment cost will probably be greater when using cobs than with stover. The costs of gasification equipment may also be influenced by the type of biomass used as fuel, thus altering the relative economics concerning the choice of biomass.

In conclusion, the break-even investment cost for gasification equipment is positive under existing technology and prices when using either cobs or stover as a fuel source for drying. This indicates that cobs or stover can compete with LP gas under present economic conditions so long as investment is gasification equipment does not exceed the break-even values. Cobs seem to be a more economical source of fuel than stover, and grain is not presently an economical energy substitute for LP gas.

Table 2. Modification to the base condition values given in Table 1.

No.	Input Description	New Value
1.	Initial grain moisture, percent	30.50
8.	Percent efficiency of drying process	40.00
9.	Percent efficiency of gasification process	80.00
16.	Change in LP gas price, percent increase from previous year	15.00
19.	Annual interest rate, percent	12.00
20.	Economic life of gasification equipment, years	15.00
22.	Harvest-transport cost for cobs in field, dollars per ton of wet material	2.50
23.	Harvest-transport cost for stover in field, dollars per ton of wet material	5.00
24.	Market value of grain at 15.5 percent moisture dollars per bushel	2.00

Computed break-even investment costs using the above values, ¢ per dry bushel (U.S. No.2):

Grain	158.58
Cobs	262.73
Stover	241.95

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