Economic and Policy Assessment of the Potential for Ethanol and Distillers' Feeds in Oregon

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ECONOMIC AND POLICY ASSESSMENT OF THE POTENTIAL FOR ETHANOL AND DISTILLERS' FEEDS IN OREGON

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I. INTRODUCTION

The intent of this report is to provide an economic and policy assessment of the feasibility of producing ethyl alcohol (ethanol) and distillers' feeds in Oregon. Potential buyers and producers, as well as concerned policymakers, are facing decisions regarding this popular issue. Consumers have been led to believe that fuel alcohol is a viable substitute for liquid petroleum fuels. Farmers see it as an avenue to secure a reliable, possibly inexpensive fuel supply and as another market for their crops. Policymakers must determine the role of ethanol in the state and are dealing with the social questions of income distribution impacts, i.e., who receives the benefits and who pays the cost of subsidies and incentives.

This report examines the demand for ethanol as a substitute for more conventional liquid fuels. Specifically, it looks at the advantages and disadvantages of converting from petroleum to alcohol use in the agricultural sector and the implications of increasing ethanol production.

Ethyl alcohol is produced by fermenting grains and other agricultural products or residue, generally referred to as biomass. The feedstock is the input to the process which consists of fermentation and distillation. The output of the process consists of ethanol, distillers' feed, and carbon dioxide.

The market for distillers' feed and its potential use as a protein substitute in conventional animal feeds also are evaluated in this report. To estimate the market value of distillers' feeds, a least-cost ration computer program was used to compare them to a wide range of livestock feeds.

The cost and availability of feedstocks in Oregon are major factors in ethanol and distillers' feed production. This report inventories these feedstocks and divides them into four categories: 1) commercial crops, 2) unused crops, 3) cellulose crops, and 4) experimental crops.

To evaluate production costs, three still budgets have been developed. These include a farm still (20,000 gallons per year production), a community/co-op still (one million gallons per year), and a large, commercial still (50 million gallons per year). Sensitivity analysis was done for each still.

Finally, this report addresses such questions as how much ethanol can Oregon produce and what impacts will increased production have? Can and should Oregonians subsidize alcohol production and for whose benefit? While this report does not provide all the answers it provides a good data base to start from.

II. SUMMARY

It is unlikely that ethanol production in Oregon will substitute for a large portion of the state's liquid fuel needs in the near future. In fact, if all wheat, potatoes, sugar beets, oats, and corn grown in the state were used in ethanol production, only about 210 million gallons, or 20 percent, of the state's gasoline and diesel fuel needs could be met. Almost the entire wheat crop in Oregon would be required just to meet the agricultural fuel needs of the state.

Since it is extremely unlikely that the entire commercial production of these crops would be used to make ethanol, a more realistic assumption of 10 percent diversion to ethanol production was made. Alcohol fuel plants are assumed to convert agricultural products to alcohol at 80 percent of the maximum theoretical conversion ratio. Based on these more limiting assumptions, it would be possible for Oregon to meet approximately 1 percent of its total liquid fuel needs and 20 percent of the agricultural fuel needs.

In addition to diverting commercial crops for ethanol production, unused or "waste" crops are often cited as potential feedstock. Whey, a by-product of the dairy industry, could produce approximately 1.6 million gallons of ethanol annually. Unharvested fruits and vegetables may account for approximately 3.7 million gallons and potato waste approximately 7.5 million gallons. Although this amounts to 12.5 million gallons annually, it is important to realize that nearly all these waste products are already being used. They are not "free." For example, cull potatoes during 1980 had a feed value of approximately $18 per ton, and any ethanol plant planning to use them must be prepared to bid them away from the livestock market.

Cellulose may have the largest ethanol production potential for Oregon. Cellulose residues and crops available from agriculture include grain and grass straw and hay forages as well as logging wastes. However, there is no adequate large-scale technology for cellulose conversion of feedstocks.

There are several potential "energy crops" that might be produced in Oregon and used as feedstock for ethanol and distillers' feeds. These include alcohol potatoes, fodder beets, Jerusalem artichokes, forage sunflowers, and sweet sorghum. For these crops to substitute for presently grown agricultural crops, combined returns from sales of ethanol and distillers' feeds would have to exceed the returns for traditional commercial crops. Furthermore, high yielding energy crops for commercial ethanol production are still in a development stage and additional research is needed.

The economics of ethanol production are highly sensitive to feedstock costs and ethanol yield per unit of feedstock. In this study, stills of three sizes are analyzed: a 20,000-gallon per year farm still; a one-million gallon per year cooperative still, and a 50-million gallon per year commercial still. Five feedstocks--wheat, barley, corn, potatoes, and sugarbeets--were analyzed for the production of ethanol and distillers' feed in each of the stills. The cost of production estimates include fixed costs, operating costs, and feedstock costs. The feedstock cost is a major portion of total cost, and increases as a portion of total cost from smaller to larger plant size.

The costs include capital and operating costs for drying the distillers' feed, and assume that the plants are designed to handle different feedstocks at the same plant costs. Alcohol output was estimated on the basis of an 80 percent conversion efficiency.

Feedstock costs comprise approximately one-half the total cost for the farm still and increase to 84 percent of the total cost of production for the commercial still. The relative impact of changes in the various factors on the cost of production depends on the size of the still and whether it is automated.

The ethanol still budgets developed for this study indicate there are decreasing costs associated with increasing size of plants up to 50 million gallons annual production. However, there may be a trade-off between economies of plant size and increasing feedstock costs as feedstocks are transported over long distances to meet input requirements of the plant. In such case, the optimal size plant may be much less than 50 million gallons.

Economic literature demonstrates economies of size in production but there is some question as to when the economies of size are reached, and where costs of production may eventually increase with larger facilities. The budget data indicate that the 15,000-gallon farm still is more expensive per gallon of ethanol production than the co-op still that produces approximately one million gallons per year. However, plants producing between three and four million gallons annually may be cost-competitive with the 50 million-gallon still.

If economies of scale are reached at the four million gallon level, then the construction of plants might be dictated by feedstock availability in addition to economies of size. In this case, there would be much greater flexibility in plant location.

In addition to ethanol, a return from the distillers' feed co-product is necessary to cover the total cost of production. Estimating the value of distillers' feeds is difficult because there are no established markets in Oregon. This study estimates the market value of distillers' feeds through the use of a least-cost computer livestock feeding program. The program was employed to simulate the use of distillers' feed in a variety of livestock feeds including a beef feeder ration, a beef finishing ration, and a dairy ration. Soybean meal, corn silage, corn, barley, hay, and other feed supplements were offered in a ration at their current prices. Each distillers' feed was then offered in the ration at varying price levels. At high distillers' feed values, the computer feed program would call for only small amounts of the distillers' feed. But as price dropped typically it would include more and more of the distillers' feed in the ration until a feeding limitation was met.

The study emphasizes that demand for distillers' feeds depends on relative prices, availability of substitutes, and domestic as well as export demand for distillers' feeds. There may be a potential for using this feed in hogs, sheep, chickens, and turkeys.

To increase the production of alcohol and reduce the nation's dependence on imported fuels, tax subsidies have been offered on both the state and federal levels. At the federal level, alcohol-gasoline blends (gasohol) of 10 percent or more alcohol qualify for exemption from the federal Motor Fuels Excise Tax. This subsidy amounts to 4 cents per gallon of gasohol or 40 cents per gallon of alcohol. There is also a federal tax credit which provides an equivalent subsidy for alcohol of less than 200 proof.

Alcohol production is also encouraged by a total federal investment tax credit of 20 percent for ethanol facilities. This includes a 10 percent energy investment tax credit on equipment that converts biomass to synthetic fuel, plus the regular 10 percent investment tax credit.

Oregon, unlike some other states, does not exempt gasohol from state fuel taxes. Rather, Oregon is encouraging alcohol production by giving investment credits against state income taxes, property tax exemptions, state income tax exemptions, and by supporting a loan program.

State and federal tax exemptions and investment credits together may make alcohol plants appealing to investors who can benefit from tax incentives. The issues are not clear-cut, and site-specific conditions are difficult to ascertain.

As a final step in assessing overall economic feasibility for ethanol production, the study combined previous findings concerning cost of production, feedstock availability, and demand for ethanol and distillers' feeds. A linear programming computer model was developed to estimate annual break-even costs per gallon of ethanol for three alternative still sizes: 3 million gallons, 15 million gallons, and 43 million gallons.

Three feedstock alternatives were considered: cull potatoes, barley, and wheat. The quantities of the feedstock available were specified at the level currently produced in Oregon. These feedstocks were priced at current market values.

The demand for distillers' feed was assumed to be limited by the numbers of livestock fed in the state. Distillers' feed prices in the ration were estimated as described earlier. Although the demand for ethanol was not restricted, the price was tested over a range from $1.50 a gallon to $2.60 a gallon.

The economic feasibility analysis indicated that a return of at least $1.50 per gallon of ethanol is necessary to economically produce ethanol, given feedstock prices and distillers' feed values. At the high level of ethanol production, (43 million gallons annually), approximately 3 percent of the annual gasoline consumption for Oregon could be achieved, but at a break-even cost considerably above current prices of unleaded gasoline. Furthermore, at this level of production, feedstock requirements would exhaust all the cull potatoes, most of the barley, and almost one-third of the wheat produced in Oregon.

It must be recognized that the assumptions made to assess feasibility in this study are restrictive regarding feedstock selection, still size, and product prices. These results, therefore, cannot be routinely generalized for all other possible situations. However, the findings do indicate that economic feasibility of ethanol production in Oregon may be presently constrained by the availability of low-valued feedstocks.

The short-run prospects appear most promising for producing ethanol from such agricultural by-products as cull potatoes. To achieve successively higher levels of ethanol output will require greater dependence on commercial crops. The higher valued commercial crops significantly increase feedstock costs and resulting break-even costs of ethanol.

III. POTENTIAL DEMAND FOR ETHANOL IN OREGON

The potential demand for ethanol in Oregon hinges upon its ability to substitute for gasoline and diesel. The extent to which ethanol fuels will substitute for existing liquid fuels depends upon the relative performance of ethanol as a fuel and the relative prices of gas, diesel, and ethanol. Ethanol production costs are higher than those for gasoline or diesel but economic incentives such as tax rebates and entitlements make ethanol competitive.

Fuel Consumption in Oregon

Oregonians used just under 1.4 billion gallons of gasoline in 1979. Preliminary indications are that this total will be lower in 1980 [Oregon Department of Energy, unpublished data]. Data on diesel use are not available beyond 1978, when more than 191 million gallons were used in Oregon (Table 1).

Agricultural fuel use data for 1974 and 1978 indicate a large increase over that time. Oregon agriculture used about 53.5 million gallons of gasoline and about 40 million gallons of diesel in 1978. It is difficult to estimate current fuel consumption, but Table 1 presents rough guidelines on the quantity demanded in Oregon. Gasohol and ethanol fuel might substitute for part of this consumption.

Fuel Prices Paid by Oregonians

Fuel prices paid by Oregon farmers have more than doubled since January 1979. For example, diesel fuel in January 1979 was 46 cents a gallon. By December 1979, it was 81 cents and by May 1980, 98 cents. Table 2 figures indicate that bulk rates for delivered regular gas and service station prices for unleaded gas have made similar increases.

Table 1. Gasoline and Diesel Use in Oregon

Year	Total Disappearance: Gasoline (Billion Gallons)	Total Disappearance: Diesel (Million Gallons)
1975	1.22	136.14
1976	1.31	141.15
1977	1.37	168.34
1978	1.43	191.65
1979	1.38	NA
	Agricultural Use	
Year	Gasoline (Million Gallons)	Diesel (Million Gallons)
1974	30.49	23.67
1978	53.49	39.89

SOURCE: Compiled from DOE Energy Data Report, 1979; USDA, ESCS Energy and U.S. Agriculture 1974 and 1978, Statistical Volume, No. 632, 1980; and Oregon Department of Transportation unpublished data.

Table 2. Fuel Prices Paid by Oregon Farmers ($/Gallon)

	Diesel	Bulk Delivery Regular (lead)	Service Station (unleaded)
January 1979	$ .46	$ -	$ -
December 1979	.81	-	-
January 1980	.85	.99	1.09
February 1980	.92	1.07	1.15
March 1980	.94	1.12	1.22
April 1980	.98	1.13	1.27
May 1980	.98	1.16	1.24
June 1980	.97	1.14	1.25
July 1980	.98	1.15	1.24
August 1980	1.00	1.16	1.26
September 1980	.99	1.15	1.25
October 1980	.98	1.14	1.23

SOURCE: Compiled from Annual Price Summary and Agricultural Prices, Crop Reporting Board, ESCS, USDA.

Ethanol Market Potential

In assessing the market potential for ethanol, a distinction must be made between current use or disappearance estimates of fuel, and underlying demand factors leading to these consumption patterns. Current projections indicate that the rate of growth and the underlying demand for liquid fuels are likely to decline in the future [State of Oregon]. The demand for gasoline is relatively insensitive to price increase, but the three-fold increase in fuel energy prices over the last 10 years has led to the development of energy-conserving technology. The fuel consumption of automobiles has decreased significantly in the last six years. Consumer response to conservation measures will likely become more pronounced as the price of fuel continues to increase relative to the mix of other goods and services in the economy.

The basic components of energy demand include: 1) consumer population, 2) consumer income and distribution, 3) prices and availability of other commodities and services, and 4) consumer tastes and preferences. Both population and incomes are expected to increase, thus increasing demand; while the influence of tastes and preferences, as well as the price of substitutes might be expected to decrease the demand for conventional liquid fuels.

This evaluation refers only to the demand for fuel, and not the relative price. Because of inflation, the nominal price of fuel energy may continue to increase even with constant demand.

The demand for all fuel energy products provides the basic schedule for the ethanol components, with price and output determined in an imperfectly competitive market. This imperfect market structure results in price leadership by the dominant petroleum firms. Ethanol producers, as price followers, would likely face a more elastic demand than the dominant petroleum-based firms. If fuel alcohol products can be differentiated from gasoline, price differentials might occur. This appears to be the current situation, with gasohol bringing premiums of several cents per gallon over the competitive product, unleaded gasoline [Anderson]. If alcohol should become the low cost fuel to produce, there is the theoretical possibility that ethyl or methyl alcohol would establish price. This situation could occur only if alcohol fuels represented a significant volume of the fuel market. In addition, there is a possibility that the existing petroleum industry would absorb the alcohol producers to maintain market control. In this research, two ethanol market potentials are surveyed: gasohol and high-proof ethyl alcohol.

Gasohol

The demand for gasohol is unique because the product contains elements of both gasoline and ethanol. Gasohol may be merely a transitional fuel until alcohol engines and fuel supplies are perfected [Fairbank].

Given the current fixed proportion of gasoline to ethyl alcohol in gasohol (9 parts unleaded gasoline to one part 200 proof ethanol), Table 3 shows the derived per gallon price of gasohol at various price levels of unleaded gasoline and ethanol. The gasohol prices developed in Table 3 are simply algebraic cost formulations and do not reflect market-clearing prices or account for performance differences between gasohol and unleaded gasoline [Meekhof, Mohinder, and Tyner]. However, Table 3 does illustrate two significant points: 1) as long as the cost of ethanol is higher than the cost of unleaded gasoline, the cost of gasohol will be proportionally higher than unleaded gasoline, and 2) changes in the price of ethanol have only one-tenth the impact on the cost of gasohol as do changes in the price of gasoline.

Table 3. Derived Cost of Gasohol at Different Assumed Prices for Unleaded Gasoline and Ethanol

	Ethanol Price, $/Gallon					
Unleaded Gasoline	1.00	1.25	1.50	1.75	2.00	2.25
	$/Gallon					
.80	.82	.85	.87	.90	.92	.95
.90	.91	.94	.96	.99	1.01	1.04
1.00	1.00	1.03	1.05	1.08	1.10	1.13
1.10	1.09	1.12	1.14	1.17	1.19	1.22
1.20	1.18	1.21	1.23	1.26	1.28	1.31
1.30	1.27	1.30	1.32	1.35	1.37	1.40
1.40	1.36	1.39	1.41	1.44	1.46	1.49
1.50	1.45	1.48	1.50	1.53	1.55	1.58
1.75	1.68	1.70	1.73	1.75	1.78	1.80
2.00	1.90	1.93	1.95	1.98	2.00	2.03

SOURCE: Adapted from Meekhof *et al.*, p. 16.

When the gasohol price exceeds that of unleaded gasoline, the combined elements of subsidization and consumer preference determine the price difference at which gasohol is competitive with unleaded gasoline. If current price trends continue, unleaded gasoline will be more expensive than ethanol in the near future [Tyner 1980]. Currently (1981), ethanol costs about $2 per gallon and unleaded fuel approximately $1.20 per gallon.

Subsidization

The subsidization of ethyl alcohol products such as gasohol is usually in the form of federal and, in some cases, state fuel tax exemption. The federal tax exemption of 4 cents per gallon on gasohol is magnified by a factor of 10 to create an exemption of 40 cents per gallon of ethanol based on the retail, taxed price of gasoline. This allows the market system to bid a 40 cent per gallon premium on 200 proof ethyl alcohol. The variety of market distribution systems which serve the fuel alcohol industry makes it difficult to determine who captures the 40 cent per gallon incentive. When ethyl alcohol is in short supply, fuel distributors and retailers may be in a position to capture some portion of the tax exemption.

It is also possible that, as the volume of marketed gasohol increases to the point where gasohol sales are no longer in a "price following" category, the exemption-subsidization may be reduced. Gasohol will then be sold on its own merits reflecting gasohol supply and demand conditions as related to the price levels of taxed gasoline.

In addition to the 4 cent per gallon federal tax exemption, several states have exempted alcohol fuels from sales taxes. State rebates of from 1 to 10 cents per gallon, when added to the 4 cent federal incentive, combine to provide from $.50 to $1.40 per gallon tax exemption on gasohol sales [Meekhoff, Mohinder, and Tyner]. One adverse consequence of state tax exemption is the depletion of highway funds for road maintenance. As a result, the long-term likelihood of continued state incentives for gasohol sales is questionable. Oregon does not have state tax rebates on gasohol sales; Idaho, Washington, and California all exempt some portion of state taxes on these sales (Table 4). To capture these incentives, Oregon-produced ethanol could be marketed in other states. This would occur only if the incentives out-weighed the transportation costs and if other states' incentives were not explicitly tied to local (state) production.

Consumer Preference

Based on current price levels, consumers appear willing to pay a premium of several cents for gasohol over the price of unleaded gasoline. This premium is variable, responds to market forces, and has been documented as 2 to 6 cents per gallon [Anderson]. Reasons for this willingness to pay a premium

Table 4. States Rebating Gasoline Tax on Use of Gasohol, September 1979

State	Rebate	State	Rebate
Cents/Gallon of Gasohol		Cents/Gallon of Gasohol	
Arkansas	9.5	Minnesota	2.0
California	5.0	Missouri	4.0
Colorado	5.0	Montana	7.0 d/
Connecticut	1.0	Nebraska	5.0
Florida	4.0 a/	New Hampshire	5.0
Idaho	5.0	New Jersey	5.0 e/
Illinois	7.5	North Dakota	5.0
Indiana	b/	Oklahoma	6.5
Iowa	10.0	South Carolina	4.0 f/
Kansas	5.0 a/	South Dakota	4.0
Louisiana	c/	Washington	6.0
Maryland	1.0	Wisconsin	7.0
		Wyoming	4.0

a/ Exemption reduced by 1 cent per year.

b/ Four percent sales tax exemption.

c/ Exemption of 8 cent per gallon fuel tax, 3 percent state sales tax, and local sales and use taxes.

d/ For 2 years it is 7 cents, reduced by 2 cents for each of 3 succeeding 2-year periods, with the remaining 1 cent exemption expiring in 1989.

e/ Pending.

f/ Exemption of 4 cents until 1985, 3 cent exemption in 1985-87.

SOURCE: National Alcohol Fuels Commission as cited in Meekhoff *et al*; p. 10.

for gasohol include: 1) improved automobile performance (real or imagined); 2) a desire to substitue domestic products for imported fuel; 3) a desire to substitute fuel from renewable resources for fossil fuels; and 4) product novelty [U.S. Department of Energy, June 1979].

Performance

Over time, the performance advantages or disadvantages of gasohol will be documented and reflected in the market price. Performance evidence is mixed. The energy (BTU) content of ethyl alcohol and, therefore, gasohol, is lower than petroleum gasoline [USDA, March 1980]. However, there is some off-setting value of ethyl alcohol as an octane enhancer [Tyner *et al*].

The long-term potential for sustained preference of American-produced renewable fuel products reflects an emotional input into consumer tastes and preferences. Estimates indicate that each gallon of ethanol would displace about 1.1 gallons of imported crude oil because of savings in the logistics, production efficiency, and the octane enhancement characteristics of ethanol [Raphael Katzen Associates].

<u>Ethyl Alcohol (unblended)</u>

The market potential for straight ethyl alcohol fuel has not been tested extensively in the United States since World War II. There are several perceived advantages of using unblended alcohol as a fuel. First, the alcohol need not be distilled to 200 proof, reducing the need for sophisticated distillation techniques associated with proportionally higher costs. (To mix with gasoline, alcohol must be 200 proof.) This may be particularly important for smaller still production and agricultural use because it is simpler and less expensive. Secondly, unblended alcohol burns more efficiently than gasoline so delivering more power per BTU of energy [Meekoff, Mohinder, Tyner]. Alcohol fuel reduces the need for blending and other logistical requirements of gasohol. The Crude Oil Windfall Profit Tax Act of 1980 has affirmed a tax credit provision for the on-farm use of ethyl alcohol fuel based on proof.

The drawbacks to unblended alcohol fuel relate primarily to the lack of direct interchangeability between unblended ethyl alcohol, gasoline, and diesel. Engine modifications are necessary for use of unblended ethanol in either diesel- or gasoline-powered vehicles. As a result, the benefits which the individual firm might gain from the use of ethyl alcohol may be overshadowed by logistical problems. Technological advances for the use of unblended alcohol fuel could solve this problem [Fairbank]. Also, even 200 proof alcohol contains only about two-thirds the energy of gasoline, and the increase in efficiency is not sufficient to make alcohol and gasoline equivalent per gallon. Moreover, lower proof alcohol contains a higher proportion of water and even lower BTUs of energy.

In addition to the demand for ethyl alcohol as a liquid fuel, there also may be a demand for ethanol from the industrial chemical sector. In the past, high valued petroleum-based chemicals such as ethelene have satisfied this industrial demand. Ethyl alcohol is beginning to compete in this market on a cost basis but the potential market volume has not been estimated.

IV. OREGON FEEDSTOCK INVENTORY AND ETHANOL POTENTIAL

To inventory and estimate the potential supply of various feedstocks in Oregon, the crops have been divided into four categories: 1) commercial crops, 2) unused crops, 3) cellulose crops, and 4) experimental crops. This division distinguishes between those crops produced for an existing market, and those crops which may become significant in the future.

Commercial crops with major potential ethanol production in Oregon are barley, corn, wheat, potatoes, and sugar beets.[1/] Any large increase in the demand for these crops for ethanol production will necessarily compete with demands for feeds or for human consumption.

A certain percentage of commercial crops in any given year is unused and can be broadly classified as culls and wastes. Cull crops are those left in the field or unsold in commercial markets. Wastes are unused crop residues from a processing plant.

Cellulose crops include straw from grains and grasses, forest wastes, and unharvested forages. These are not currently used as feedstocks for ethanol production because there is not a commercially cost-effective process of hydrolysis. Experimental crops include sweet sorghum, Jerusalem artichokes, fodder beets, big potatoes, and other crops. These crops may provide high yielding alcohol feedstocks in the future but growing and/or processing characteristics are largely untested.

By using liquid fuel use in Oregon and ethanol market potentials, projections of feedstock requirements can be made for various ethanol output levels. Table 5 summarizes Oregon feedstock inventories, alcohol conversion

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1/ 1975-1979 production and prices are described in Appendix 1.

ratios, and estimates of alcohol output derived commodities with known conversion factors. Only subjective valuations can be drawn for commodities lacking standardized conversion rates. The feedstock inventory figures in Table 5 cover existing agricultural commodities. Additional agricultural products designed specifically for alcohol production, such as fodder beets or additional corn acreage, could add to the feedstock supply. However, shifting to specialized alcohol feedstock crops could result in reduced production of existing commodities. Forest products are not included in this feedstock inventory because the technology needed to convert them to alcohol is different.

Oregon Department of Transportation (DOT) statistics indicated that Oregon motor vehicle gasoline consumption in 1979 was 1.38 billion gallons. This represented a 4 percent decrease from 1978 levels. Oregon DOT estimates for the first 6 months of 1980 revealed a 7.8 percent decline in gasoline consumption over the 1979 levels. The feedstocks necessary to produce the ethyl alcohol required to replace specified levels of current gasoline consumption were estimated, using these gasoline consumption figures and the alcohol conversion ratio of basic crop materials in Table 5. Based on 1979 Oregon gasoline consumption, substituting 1 percent of current gasoline consumption with an equivalent alcohol volume would require roughly 13.8 million gallons of ethyl alcohol. This could make 138 million gallons of gasohol which would fulfill Oregon's gasoline demand.[2/] The maximum potential volume of ethyl alcohol from agricultural crops (for which conversion ratios exist) is estimated

[2/] Because of the lower BTU value of ethanol, it is likely that a proportionately larger volume of ethanol would be required to substitute for gasoline on an energy-equivalent basis.

at approximately 373 million gallons. This figure reflects the maximum theoretical yield calculated from the average fermentable sugar content.

Table 5. Feedstock Inventory and Ethanol Conversion Potential for Oregon Agricultural Commodities

Commodity	Oregon 1975-79 5 Yr. Ave. Production Level b/	Theoretical Conversion Rate c/	Ethanol Output Potential a/: At Maximum Theoretical Conversion	Ethanol Output Potential a/: At 80% of Theoretical Conversion
(units)		(gal/unit)	(mil.gal.)	(mil.gal.)
Wheat (bu)	55,037,200	2.6	143.1	114.5
Potatoes (cwt)	26,533,800	1.4	37.2	29.7
Barley (bu)	8,809,600	1.9	16.8	13.4
Sugar Beets (ton)	275,400	20.0	5.5	4.4
Oats (bu)	4,281,200	1.0	4.3	3.5
Corn for Grain (bu)	1,010,700	2.6	2.6	2.1
Subtotal			209.5	167.6
Whey (ton)	192,420	8.3	1.6	1.3
Straw (ton)	62,800	35.0	2.2	1.8
Hay (ton)	2,463,800	30.0	73.9	59.1
Fruits (ton)	322,100	11.5	3.7	3.0
Crop Residue (tons) d/	2,332,015	35.0	81.6	65.3
Subtotal			163.0	130.5
Processing Veg. (ton)	505,698	n.a.	--	--
Onions (cwt)	4,266,000	n.a.	--	--
Corn Silage (ton)	666,200	n.a.	--	--
Total			372.5	298.1

a/ Output potential should not be routinely interpreted as economically or technologically efficient.

b/ Production data obtained from the Extension Economic Information Office, Oregon State University.

c/ Conversion rate estimates vary, particularly when starch or sugar content vary [Garthe, Miller, Jacobs, and Newton].

d/ Supply based on straw (tons) to grain (bushels) ratios of: wheat - .0375; oats - .0213; barley - .024; corn - .028 [Intergroup Consulting Economists, Ltd].

The experience of alcohol production plants revealed that efficiencies in conversion are more likely to approach 80 percent of the theoretical value

[Miles]. An 80 percent conversion of the available feedstock inventory in this case would result in approximately 298 million gallons of 200 proof alcohol. In perspective, these estimates suggest that even if the entire agricultural feedstock inventory were converted to ethyl alcohol only about one-quarter of Oregon's gasoline consumption requirements could be met.

Because of the tentative nature of the alcohol production estimates, and the even more unlikely possibility that all agricultural commodities would be converted into alcohol fuel, the above estimates likely would never be realized. However, the fundamental relationship between total feedstock inventory and gasoline consumption establishes some parameters so alternative ethyl alcohol production levels can be assessed.

The use patterns of the "potential" feedstock inventory is of foremost importance. Virtually all feedstock inventory is already committed to market outlets, and technical feasibility of conversion to alcohol is not synonymous with economic feasibility.

An alternative procedure for estimating potential alcohol production and resulting feedstock demands is to determine the portion of each crop that might economically be diverted to alcohol production. Such an approach takes note of both costs and existing demands for the individual commodities.

Price Elasticity of Supply for Feedstocks

The price elasticity of supply expresses the percentage change in quantity supplied in response to a given percentage change in price, holding other factors constant. Conceptually, with historical supply relationships the price of a given feedstock will increase as the demanded quantity increases. The basic variables governing the resultant supply response include the magnitude of the aggregate supply, the nature of the cost function, and available alternative uses of the resources. An inelastic supply (a percentage change of less than 1) implies that increases or decreases in the price of a commodity cause relatively smaller changes in quantity supplied. An elastic supply (percentage change greater than 1) implies a supply change proportionately larger than the change in price.

Estimates of supply elasticities of major commodities are listed in Table 6.

Table 6. Estimated Short-run Elasticities of Supply for Selected Commodities

Crop	Elasticity
Potatoes	.8
Soybeans	.5
Feed Grains	.4
Wheat	.3
Fruits	.2

SOURCE: Tweeten, Luther, Foundations of Farm Policy, University of Nebraska Press, Lincoln. 1970

The "short-run" estimates in Table 6 are based on an adjustment period of about two years. Because of the longer adjustment period, long-term supply elasticities are generally higher than short-term effects. Elasticity coefficients also tend to be higher for crops produced as a side line and where numerous cropping alternatives exist. Short-run elasticities are lower for crops such as wheat, which is grown on large acreages of cropland in areas where alternatives are limited [Tomek and Robinson].

The current level of irrigated corn production is probably too small to be considered a major feedstock for large scale ethanol conversion in Oregon (Table 5). If the economics of alcohol production were sufficiently attractive, however, crop land could be shifted into corn production. Corn shipped into this region is destined primarily for export markets and is priced relatively high because of the added transportation cost.

Because of their low prices, the use of surplus, waste, cull, and generally underutilized agricultural products is a prime consideration in the feasibility of ethanol production. However, the aggregate supply of such feedstock is low relative to the underlying supply of commercial agricultural products. Price competition from other uses, such as livestock feed, food processing, soil conditioners, or other alcohol plants, must be considered. The competitive pressures brought about by a new demand for feedstocks would be expected to increase prices above existing levels. Competition from livestock feeders may be mitigated to some extent by the subsequent availability of distillers' feeds from the alcohol conversion process.

The availability of cull agricultural products is not well established or reported. Estimates have been made on the availability of cull potatoes in Oregon. These are of interest because potatoes are considered a prime ethanol feedstock and the supply relationships also may be analogous to other cull agricultural commodities.

An estimated 10 to 12 percent of the annual Oregon potato crop is culled in processing and marketing operations [Mosley; Spiruta]. In addition, roughly 8 percent of the crop is left in the field [USDA Crop Reporting Board]. These estimates imply that a significant portion of the potatoes produced might be salvageable as a feedstock for ethanol production.[3/] However, there are several additional factors to be considered.

First, the quantity of potatoes culled in a year varies, depending upon weather, disease, and market conditions. Irregular supply would be potentially disruptive to an alcohol plant. Second, other demands exist for cull

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3/ 1979-1980 crop cull potatoes have been priced from various sources at a range of from "free" to $.70/cwt.

potatoes, primarily for starch and as livestock feed. Least cost analyses of beef cattle rations at 1980 alternative feed prices suggest a value for potatoes as feed is inelastic up to $18/ton ($.90/cwt.).[4/] Thus, the cost of potatoes as an alcohol feedstock would be expected to be at least equal to that level because of competition with livestock feeders. Finally, the quoted price of cull potatoes may not include any of the necessary assembly, handling, transportation or storage costs required to render the feedstock ready for fermentation. The relevant feedstock cost is the price of the potatoes delivered and ready for fermentation, rather than the price at which the feedstock can be purchased from the producer.

The supply of by-products such as whey, potato wastes, and crop residues from food processing and farming operations has a more predictable volume. As a result, the supply of these feedstocks would be fairly inelastic, particularly at higher usage levels. Research findings also indicate that as higher demands are placed on these types of feedstocks, certain institutional farming or food processing parameters may be encountered which affect supply. For example, excessive removal of crop residue is detrimental to soil conservation [Tyner et al] and the time required to accumulate the residue may interfere with established farming patterns [Apland].

Energy-specific experimental crops will be grown only if economically feasible. Since there may be only limited alternative market outlets for these commodities, the quantities produced would be more closely attuned to feedstock demands through contractual commitments between the alcohol plant and the producer.

4/ Calculation based on an Agnet least cost ration for feeder cattle. On an "as fed" basis, potatoes comprised 66 percent of the ration from $2/ton up to $18.31/ton.

The availability of feedstocks is also a direct function of distance. Typically, low value feedstocks are uneconomical to transport over long distances given increasing transportation costs. For bulky, perishable feedstocks such as whey, potatoes, or food processing wastes, location of the feedstock source may dictate location of the alcohol conversion facility. Other logistical considerations in feedstock utilization include the flow and and availability of the feedstock over the year, storage and handling requirements, and the compatibility of different feedstocks in the conversion process.

Ethanol from Commercial Crops

By drawing on the commercial agricultural commodities grown in Oregon (Table 5), 209.5 million gallons of ethanol could be produced, using all wheat, potatoes, barley, sugar beets, oats, and corn for grain grown in the state. Assuming an 80 percent overall efficiency in plant production, this figure drops to 167.6 million gallons a year. In 1978, Oregonian agriculture used 93.38 million gallons of gasoline and diesel. This means that about half the commercial agricultural production in the crops listed above would have to be used to meet agricultural fuel needs. In other words, almost all the wheat production or all the potatoes, barley, sugar beets, oats, and corn for grain in Oregon would have to be converted to ethanol to meet the gasoline and diesel requirements of Oregon agriculture.

In 1978, Oregon gasoline and diesel consumption was approximately 1.7 billion gallons. Agricultural use was approximately 5.33 percent of this total. Using all the commercial crops listed above, ethanol could be produced to meet 9.5 to 12 percent of Oregon's total diesel and gasoline needs.

It is very unlikely that all the commercial commodities listed above would be converted to ethanol production. If 1/10 of the feedstocks were diverted from agricultural feed and food uses to ethanol production, about 1 percent of the total gasoline and diesel use in Oregon could be met. Converting 1/10 of the current feedstocks would meet approximately 20 percent of the agricultural needs of the state.

Unused Crops and Their Ethanol Potential

Unused crops are often cited as a potential feedstock to produce ethanol. Unused crops as defined here fall into two categories: culls and wastes. Cull crops include potatoes left in the field, fruits and vegetables left in the field, and distressed grains not making grade for export and or processing. Waste crops include those products left over from processing including potato wastes, whey, and fruit and vegetable cannery wastes.

It is difficult to measure quantities of crops left in the field; the quantity of unharvested fruits and vegetables may run as high as 25 percent, and sources estimate that approximately 8 percent of the potato harvest is left in the field (Table 7). There are also reliable estimates of distressed grains available in the state. In a good year, most of the grain in the state meets government standards; however, when weather conditions are poor as much as 20 percent of the crop may be distressed [Geotze]. The processing of fruits and vegetables leads to an estimated 8 percent waste with potato wastes estimated at about the same level [Mosley].

Whey is a dairy industry by-product with potential for conversion to ethanol; the average production has increased from approximately 340 million

Table 7. Potatoes Left in Field at Harvest

Year	Weight (cwt per acre) left in field at harvest	Acres harvested	Total Weight (cwt) left in field at harvest	Average field per acre (cwt)	% of crop left in field
1975	36	55,500	1,998,000	440	8.18
1976	34	65,600	2,230,400	441	7.71
1977	38	60,000	2,280,000	426	8.92
1978	31	67,600	2,095,600	421	7.36

SOURCE: USDA Crop Production Reports, December 1975, 1976, 1977, and 1978; and "Fall Potatoes" Commodity Data Sheet, OSU Extension Service, Extension Economic Information Office, OSU.

tons per year. Whey production has increased from approximately 340 million pounds in 1975 to almost 420 million pounds. Approximately one-half of whey production is exported under long-term contract [Adams].

Table 8. Oregon Whey Production, 1975-1979

Year	1975	1976	1977	1978	1979	Average
Quantity (m lbs.)	338.4	376.2	384.3	406.8	418.5	384.8

SOURCE: Adams.

Whey waste, fruit processing waste, and potato waste are the unused crops in Oregon that appear to have the most potential for conversion to ethanol. Whey waste could produce approximately 1.6 million gallons of ethanol, fruits approximately 3.7 million gallons, and potato waste approximately 7.5 million gallons for a total of 12.8 million gallons of ethanol.[5/]

5/ See Appendix 2 for biomass to alcohol conversion factors used in this section.

Cellulose Feedstocks and Their Ethanol Potential

A third category of potential ethanol feedstocks is cellulose wastes and cellulose crops. These include straw from grains and grasses, forest and timber wastes, and forages. It is difficult to estimate the cellulose crop supply, but some data have been developed for this report.

For grains it is estimated that from .02 to .05 tons of straw is produced per bushel of grain (Table 9). Straw harvest for ethanol feedstocks would vary, depending on the length of straw produced by the grain and the quantity of straw desired for soil conditioning and erosion control.

Table 9. Straw Production Estimates (Straw Tons to Grain Bushels Ratio)

Crop	Ratio[a/]	Crop	Ratio[a/]
Wheat	0.0375	Flaxseed	0.0420
Oats	0.0213	Rapeseed	0.0500
Barley	0.0240	Mixed Grains	0.0118
Rye	0.0560	Grain Corn	0.0280

[a/] Other sources indicate that this ratio may be low.

SOURCE: Intergroup Consulting Economics, Ltd.

Cornstock production is estimated to approximate that of the grain weight. Thus, a ton of grain would be associated with approximately one ton of cornstock [Paige and Boulton].

Forests wastes potentially available for ethanol production could come from three sources: mill residues, logging residues, and mortality. In 1976, about 15.4 million dry weight tons of wood and bark residues were created as mill residues in Oregon. Of this total, 510,000 tons were reported unused. This volume represents a source of feedstock for ethanol production.

Logging residues, in contrast to mill residues, are not in a readily usable form and require chipping as a minimum processing step. They also would have to be logged, loaded, and transported to an ethanol mill. Transportation could be costly because of the product's low density and the distance to the processing facility.

Data from the 1980 National Timber Assessment indicate 181 million cubic feet of growing-stock logging residues (logs and branches more than 4 inches in diameter) are generated in western Oregon, and 26 million cubic feet in eastern Oregon. This converts to a dry basis of about 2.6 million tons. As shown in Table 10, nongrowing stock from previously dead, cull, or noncommercial trees on harvested areas is approximately equal to the growing stock portion. Thus, the total volume in Oregon is approximately 5 million oven-dried tons annually [USDA Forest Service].

The main stem portion of logging residues (more than 4 inches in diameter), indicated above, is estimated to be slightly less than 50 percent of the total biomass generated during logging. This would mean that the total biomass of logging residues in Oregon approximates 10 million dry tons. Efficient management of logging production requires leaving some material on the ground. This would tend to reduce the total available. Still, considerable volume would be available for ethanol feedstock production [USDOE, June 1979].

In the last few years, several million board feet of timber have been bug-killed by the tussock moth and mountain pine beetle in the Blue Mountain area. Some studies indicate that the total is approximately 1.3 billion board feet, or 1.36 million dry tons [USDA Forest Service]. If this volume is harvested in time, it has value for solid products and pulp chips. Much of the material not suitable for these products has value as an ethanol biomass. This volume increases as the trees deteriorate in quality over time. It is estimated that the timber killed by insects in northeastern Oregon will be physically available for approximately 20 years.

The total unused logging residues in Oregon are estimated at 10 million dry tons annually. Theoretically, this could convert to 470 million gallons of ethanol per year.

In eastern Oregon there are approximately 1.36 million dry tons of bug-killed timber which theoretically could be converted into approximately 64 million gallons of ethanol over the next 20 years.

Hardwoods on the west side of the Cascades represent a little-used resource. The harvest is less than 1/3 of 1 percent of the total inventory volume, estimated at 4.8 billion cubic feet on commercial forest lands. In 1976, 65.5 million board feet or approximately 13 million cubic feet of hardwoods were harvested. A rough estimate, including noncommercial lands, is that 1-2/3 times the reported inventory volume exists, i.e., more than 8 billion cubic feet of hardwoods. If the management practice of converting hardwood stands to softwood stands is continued, a good portion of this supply of biomass may be available in the future [USDA Forest Service].

Oregon produces more than 2.4 million tons of hay annually, a total fairly constant for the last five years. The value of this crop production is estimated at $154 million; the value of sales in 1979 was approximately $43 million. Hay is produced on 1 million acres of land and in every county of the state. Hay lands include alfalfa, clover-grass, small grain, and native meadow (wild) hays.

Alfalfa acreage totals more than 400,000 acres, with 90 percent in eastern Oregon. Malheur County has approximately 56,000 acres. Baker and Klamath

Table 10. Forest Wastes

		1976		1980
Mill Residues				
Total	=	15.4 mil. tons dry wt.		
Unused	=	510,000 tons		
Logging Residues (growing stock portion over 4" dia.)				
Total			=	2.6 million dry tons
Western Oregon			=	2.2625 million dry tons
Eastern Oregon			=	.3250 million dry tons
Logging Residues (nongrowing stock portion over 4" dia.)				
Total			=	2.6 million dry tons
Western Oregon			=	2.2625 million dry tons
Eastern Oregon			=	325 million dry tons
Logging Residues (includes growing and nongrowing over 4" dia.)				
Total			=	5.2 million dry tons
Logging Residues (including all biomass under 4" ida.)				
Total			=	10* million dry tons
Mortality				
Insect damage (Blue Mountain area) (Physically available for 20 years)			=	1.3 billion board feet

* Mainstem logging residues are estimated at slightly less than 50 percent total biomass, thus, total biomass would be approximately 2 times that estimated for mainstem residues.

SOURCE: Constructed from data in USFS publication and Wood for Energy in the PNW - An Overview, USDA Forest Service Pacific NW Forest and Range Experiment Station, General Technical Report PNW-94, September 1979.

counties each have approximately 39,000 acres. Much of the alfalfa hay is utilized on the farm on which it is produced, with approximately 20 to 25 percent sold as a cash crop. Primary markets include dairy farms in western Oregon. Smaller amounts are sold for beef cattle, sheep and horse feed, and export.

Approximately 220,000 acres of clover-grass hay are produced annually--mostly in western Oregon. Most of this crop is utilized on the farm. About 80,000 acres of grain hay are grown in the state. More than half is grown in the south central area of Oregon. The remaining acreage of hay, more than 340,000 acres, is native meadow hay, with approximately one-half of the acreage in Harney and Lake counties. Almost all wild hay is utilized on the farm or ranch.

A rough estimate of the amount of ethanol available from all the hay forages in Oregon would be 74 million gallons per year.

Experimental Energy Crops

There is little published data relating to experimental crops potentially available for ethanol production in Oregon. Fodder beets, sweet sorghum, and Jerusalem artichokes are often discussed. Since management and production practices for these crops are unclear, no supply estimates can be substantiated at this time. A brief discription of each is included.[6/]

Fodder Beets

The fodder beet, a cross between the mangel and the sugar beet, yields 25 gallons of alcohol per ton. With 3 to 5 years of plant breeding, a commercial fuel beet with yields as high as 50 tons per acre (compared to the smaller sugar beets at 25 tons) may be available. Since cultural practices and equipment probably would differ little from sugar beet production in eastern Oregon or table beet production in the Willamette Valley, Oregon farmers should be able to shift into fodder beet production.

6/ Summarized from an unpublished report by Mike Stoltz, Lane County Extension Agent, September 1980.

Idaho is developing a variety of fuel beet from fodder beets and sugar beets with high producing, high sugar, disease resistant characteristics.

Jerusalem Artichokes

The Jerusalem artichoke belongs to the sunflower family and is native to North America. Research in the 1920s and 1930s demonstrated that Jerusalem artichokes were ideally suited for production in the Willamette Valley. Yields of 20 tons per acre with 19 percent total sugar were obtained.[7/] Current work shows up to 28 gallons of alcohol produced per ton of tubers with up to 34 tons produced per acre.

Harvesting the green stems (22 to 25 percent sugar) precludes tuber production but total sugar per acre should be much greater. The sugar extracted from the stems must be sterilized or concentrated to 80 percent sugar for storage.

Sweet Sorghum

A small amount of sweet sorghum is grown for table sugar in the United States. Feasibility studies are under way to determine its climatic requirements. Although sorghum tolerates a wide range of climate and soil conditions, its potential is questionable in Oregon because the high temperatures necessary for crop development occur only in a limited area.

Alcohol Potatoes

Alcohol potatoes are large, commercial potatoes grown for their size and starch content. Their ethanol yields are the same as from commercial potatoes. Plant geneticists predict that, with 3 to 5 years of breeding, tubers will weigh 10 to 12 pounds and yield 40 to 50 tons per acre.

7/ One pound of sugar yields .5 pound of alcohol, and 13.5 pounds of sugar yield 1 gallon of alcohol, according to USDA studies of the culture and certain varieties of the Jerusalem artichoke.

The Columbia Basin area offers good climatic conditions for alcohol potato growth. The relatively dry climate, low rainfall, and humidity allow timely planting and late fall harvest. The fine sand and silt loam soils make land preparation cost low and harvesting easy.

Although cultural practices are similar to those for commercial potatoes, research suggests that the alcohol potatoes would use plant nutrients and water more efficiently. Smaller amounts of soil fumigants, insecticides, and fungicides are needed because cosmetic blemishes, hollow heart, and other defects do not reduce tuber value.

Crop Storage and Transportation Characteristics

In addition to the initial cost of a feedstock, storage and transportation characteristics enter significantly into determining the cost of using any feedstock for ethanol production.

Wheat and barley are harvested in mid-summer and because of their nonperishability, can be stored under proper conditions for a number of years. In 1971, the Pacific Northwest had storage capacity of 100 million bushels on farms, 232 million bushels in country elevators, 15 million bushels at subterminals, and 35 million bushels at terminals. Capacity has continued to increase, especially at the farm level [RRC 1980].

Wheat and barley could be readily available throughout the year as ethanol feedstocks. Using these feedstocks, large stills could contract for farm and local elevator storage and save storage capital costs.

Corn is produced using many of the same general cultural practices as wheat and barley but is normally dried after harvest before storage. Once dried, corn has marketing and transportation qualities similar to other grains.

Potatoes are bulky, high in moisture and have to be stored in specially designed sheds to avoid quality loss. They are harvested from July to November and have a storage life of approximately one year. The quality of the potato for alcohol production is not important but the potato must maintain its chemical composition over time. Potatoes with changed chemical compositions do not convert to alcohol on a weight basis the same as fresh potatoes.

Potato processing plants usually operate continuously from August through June. Supply of processing wastes is fairly constant but potato processing wastes deteriorate quickly and are easily contaminated if not used within one or two days.

Sugar beets are more perishable than potatoes but can be stored outside. However, freezing causes chemical breakdown decreasing ethanol production per weight unit.

Fruit processing, except for apples and pears, is concentrated in the summer. Pears tend to have a longer processing period and apples can be stored and processed throughout the winter. Approximate processing dates for these Oregon commodities are presented in Table 11.

Table 11. Commodity Processing

Commodity	Processing Date
Apples	9-15 to 5-18
Blackberries	8-10 to 9-30
Blueberries	7-20 to 8-31
Cherries	6-20 to 7-20
Peaches	8-15 to 10-10
Pears	8-10 to 12-15
Plums	8-15 to 9-30
Raspberries	5-29 to 7-15

These processing dates indicate product and processing waste availability. Any ethanol plant using these commodities would need substitutes for other times of the year to operate on a continuous 12-month basis.

Transportation costs are difficult to generalize because rates vary on different carriers depending on the commodity and minimum weight rates. Data in Table 12 shows representative shipping rates for various commodities in Washington and other parts of the Pacific Northwest. In addition to the rates shown in Table 12, raw or unmanufactured agricultural products moving in interstate commerce by motor carrier are exempt from rate regulation, and collection costs more closely parallel truck operating costs.

Freight rates have become more variable under recent legislation to deregulate railroad and truck transportation. As a result, transport costs must be estimated on a site-specific basis for a given ethanol conversion plant. Nonetheless, feedstock collection costs will continue to be a function of distance, volume, and backhaul potential.

Table 12. Commodity Rates (Cents per Pound of Commodity Shipped)

Commodity	Minimum Shipment Weight	Rate Formula
Grain, 1978 (by rail)		.14166 (x)[a/] .33525 + .14166(x)
PNW Intraregional Truck Rates, 1980		
Peas, shelled; lima beans, shelled; asparagus; carrots; cauliflower; snap beans. fresh, in lug boxes, tote bins, or bulk loose in truck	18,000	49.397 + .3624(x)
Grain, whole, in bulk; beans; peas; lentils, dry in bulk; feed; feed mixtures or ingredients; animal or poultry, dry, in bulk	40,000	19.1847 + .3578(x)
Seed: field run; in bulk or boxes	30,000	12.8635 + .3600(x)
Livestock: sheep; goats; hogs	30,000	36.6129 + .4410(x)
Livestock: horses; mules; cattle	40,000	21.5893 + .3752(x)
Fruits: cherries, fresh, unprocessed, in bins or boxes requiring refrigerated vans	30,000	44.2179 + 1.1035(x)
Potatoes: fresh, in bins, boxes, sacks, or packages	48,000	14.176 + .4302(x)
Potatoes: loose in truck	48,000	10.9888 + .3587(x)
Fruits: unprocessed, fresh, not cold pack or frozen, bins or bulk	40,000	19.0384 + .3913(x)

[a/] x = miles transported.

SOURCE: Formulas estimated from "Fruit and Vegetable Truck Cost Report," USDA Office of Transportation, and from the Washington State Utilities and Transportation Commission, Local and Joint Freight Tariff No. 4-A, 1978.

V. COST ESTIMATES FOR BIOMASS FERMENTATION

In this section, budgets are constructed for three size stills: a 20,000-gallon still (farm still), a one million-gallon still (co-op still), and a 50 million-gallon still (commercial). Budgets for the first two are based on case studies of stills in eastern Oregon. The budget for the large commercial still is based upon consolidation of published reports.

All costs are presented as totals and, for comparisons, on a per-gallon of ethanol-produced basis. However, costs do not reflect any credits for ethanol sales or distillers' feed sales, nor do they give credit for tax exemptions or other instituted economic incentives like accelerated depreciation, which may be variable or discretionary. Such returns from direct sales or from administrative subsidies have to be weighted against costs to determine net returns in a specific condition. It is not the intention of this report to do a site-specific feasibility study; rather it is to present more general data that individuals can use in making decisions regarding ethanol and distillers' feed production.

Still Description

The farm still represented in this study has a capacity of 20,000 gallons per year. The still is designed to prepare feedstock in three 400-gallon cook tanks and one 400-gallon continuous fermentation tank. These run a 6-inch distillation column. The still uses a wagon box drier for the distillers' feeds (DF) and a gasifier fueled by wood, straw, or grass waste as a heat source.

The still uses the batch method which takes approximately 36 hours. It produces about three gallons of alcohol per hour. It is assumed to operate 340 days a year, 24 hours per day. Two people, each working 8 hours a day, keep the still running. Water requirements for the still are estimated at 30 gallons per bushel of grain fermented.

This farm still is not automated. Automation would require computerizing the still, so feedstock, water, and yeasts are fed automatically. This process would be self-monitoring and nearly labor free, requiring only one hour of labor per day.

The community/co-op still represented in this study produces 1 million gallons of alcohol per year. The co-op (cooperative) still concept calls for providing feedstock and equity financing from a number of member-patrons, utilizing a common cooperative business organization. The co-op still is designed with 62,000 gallons of cooking capacity and two 36-inch distillation columns. It produces a little under 3,000 gallons a day, operating 340 days per year, 24 hours per day.

The commercial still represented in this study produces 50 million gallons of alcohol per year. This size was chosen because economies of size appear in ethanol production for plants up to 50 million gallons per year. The major pieces of the processing equipment are near maximum size at 50 million gallons, and larger plants essentially duplicate smaller plants, e.g., a 100 million-gallon plant would be two 50-million gallon plants side by side.

A number of studies have estimated the cost of commercial stills under varying assumptions [Litterman et al; Chambers; Tyner; USDA]. Many of these studies are summarized in a Rocket Research Company (RRC) report [RRC, pp. 3-14]. The RRC report updated an earlier report by Raphael Katzen Associates (RKA) to reflect first quarter 1980 economic conditions. Cost figures for this analysis are taken from this study except for feedstock costs.

Since the budgets for the three stills were developed from different sources, the cost components may vary. Cost assumptions are presented for both fixed and operating costs for all three stills.

Ethanol Yields and Plant Efficiency

The efficiency of converting a feedstock to ethanol depends on cooking, fermentation, and distillation of the feedstock. Some engineers estimate that a reasonable expectation is 90 percent efficiency in the cooking process, 90 percent efficiency in the fermenting process, and 95 percent efficiency in the distillation process [Miles]. This leads to an overall plant efficiency between 75 and 80 percent. However, many engineering and economic feasibility studies have assumed efficiency to be 100 percent, and have used the theoretical alcohol yields for various feedstocks. For example, in Table 13 the theoretical yield from a bushel of corn is 2.7 gallons of ethanol. In this study an 80 percent overall efficiency ratio is used and thus corn is assumed to produce 2.16 gallons of ethanol per bushel. (See Appendix 3 for other feedstock conversion rates.)

Table 13. Theoretical and Actual Ethanol Yields from Various Feedstocks

Crop	Unit	Theoretical Ethanol Yield (gal.)	Actual Yield (gal.) (80% Efficiency)
Barley	bu.	1.90	1.52
Corn	bu.	2.70	2.16
Wheat	bu.	2.60	2.08
Potatoes	cwt.	1.40	1.12
Sugar Beets	bu.	.72	.58

SOURCE: Adapted from Litterman, Eidman, and Jensen, Economics of Gasohol, Department of Agriculture and Applied Economics, University of Minnesota, Economic Report ER78-10, September 1978, p. 4.

Fixed Costs

Capital Costs

Capital costs must reflect investment costs which are amortized and recovered over the life of the project. In this study, capital costs are amortized by using a straight-line depreciation method and an interest charge based on the average investment (total investment divided by 2). This method converts capital expenditures into an annual cost figure. It has shortcomings because it may fail to reflect key financial parameters actually used in still operation. These include depreciation method, the capital structure, cost of debt, cost of equity, investment tax credits, federal and state income taxes, and inflation rates. It might be possible to include all these factors in a cost estimate, but they would be based on assumptions that vary widely for site-specific projects. Discounted cashflow models that reflect all these factors could be used to determine the financial effect of site-specific conditions. However, the more general approach of straight-line depreciation and interest charged on the average investment is used in this study. The result is an annual capital cost for operating the alcohol plant and a cost-per-gallon for the three base cases.

The farm still has the smallest capital cost, $44,000. A list of component parts is included in Appendix 4. Automation of the still adds $25,000 in capital costs. The community/co-op still's capital costs are $1,575,000, and the commercial still's are $63,650,000.

Insurance, Taxes, and Permits

Insurance, taxes, and permits are estimated at 2 cents per gallon of ethanol produced for the farm and community/co-op stills, and 1.6 cents for the commercial still.

Operating Costs

Labor

Labor cost estimates vary with each still. Labor is assumed to cost $5 per hour (including overhead) for the farm stills. For the community/co-op still, labor is not broken down by the hour. The yearly charge includes the plant engineer and operators. All labor associated with handling the feedstocks and by-products are:

PLANT OPERATIONS (340 days per year, 24 hours per day)		
1. Plant engineer	$ 25,000	
2. Plant operators - 3 workers per 8-hour shift x 3 shifts	155,520	
3. Grain handling, maintenance, etc. - day shift	51,840	
4. By-product handling - dryer operations including sacking and handling of brewers dried grain, wet slops, etc. - worker per shift x 3 shifts	52,840	
5. Office staff	21,600	
FEEDSTOCK OPERATIONS AND SALES		
1. Grain/feedstock acquisition	25,000	
2. Shipping - drivers	26,880	
3. Sales - 1 sales person	17,280	
TOTAL $.37/gallon		$375,960

A total labor charge is taken from published reports for the commercial still [Rocket Research Corp.]. This is not broken into any subcategories.

Energy Costs

Fuel costs for stills vary depending on the fuel available in a particular area, cost of delivery, and the specific design of the still. The estimated amount of energy needed to cook, ferment, distill, and dry fermented grains varies widely. Some estimates [Chambers] put the total requirement as low as 48,000 BTUs per gallon of ethanol. Others use 131,000 BTUs per gallon of ethanol [State of Oregon]. For the community/co-op still, 82,000 BTUs per gallon of ethanol is assumed [USDA]. Using this figure and $40 per ton coal, the fuel cost for ethanol is 19 cents per gallon. Using RRC data, fuel costs are 6.8 cents per gallon for the commercial still.

The RRC data regarding coal costs may be low, if other estimates [Chambers; USDA, March 1980] are accurate in their cost figures of approximately $.19 per gallon for steam boilers powered by coal. However, coal as a percentage of total annual costs is small as indicated by the sensitivity analysis presented later in this section.

Estimates for electricity used in ethanol production do not vary as widely as the fuel use figures. Most studies estimate .5 kwh (kilowatt/hour) per gallon of ethanol and some studies [Chambers] indicate as high as .8 kwh per gallon of ethanol. This study uses the .5 kwh figure and assumes that electricity costs 3 cents per kwh for the farm still, 2 cents per kwh for the community/co-op still, and 0.11 cents per kwh for the commercial still. One gallon of ethanol requires 1.5 cents of electricity for the farm still, 1 cent for the community/co-op still, and 1.44 cents for the commercial still.

Nontraditional sources of energy may reduce the fuel costs. For example, a gasifier used by the farm still, utilizing wood waste, straws, grass clippings, etc., reduced fuel costs in ethanol production. Also, the use of geothermal energy as a heat source reduces fuel requirements for ethanol production. In this case, a still's energy costs is 9 cents per gallon, giving 10 cents per gallon energy credit for the use of a gasifier or geothermal heat.

The 9 cents covers transportation, labor, and processing (chipping) of feedstocks used in the gasifier. Even though geothermal energy is used, a steam booster is often needed, so technology with low-grade thermal heat does not completely eliminate fuel costs for ethanol production.

Maintenance and Repairs

Maintenance and repairs are estimated at 4 percent of the original capital equipment cost annually for the farm still and commercial/co-op still. They are estimated at 1.44 percent annually for the commercial still.

Miscellaneous

Miscellaneous expenses are assumed to be $500 per year for the farm stills. For the community/co-op still they are estimated to be $10,000. Miscellaneous costs for the commercial still are 1 percent of the original capital costs plus chemical and yeast costs.

Feedstock Costs

To develop feedstock costs, the following June 1980 feedstock prices, standard weights, and ethanol yields were assumed:

Barley	48 lbs./bushel @ $2.46/bu. 41.7 bu./ton 1.52 gals. ETOH/bu.
Corn	56 lbs./bu. @ $3.50/bu. 35.7 bu./ton 2.16 gals. ETOH/bu.
Wheat	60 lbs./bu. @ $3.55/bu. 33.33 bu./ton 2.08 gals. ETOH/bu.
Potatoes	60 lbs./bu. @ $1.77/bu. 33.33 bu./ton $2.95 cwt. or $59/ton 1.12 gals. ETOH/cwt.

Sugar Beets

52 lbs./bu. @ $0.85/bu.
38.46 bu./ton
$33/ton (anticipate $45/ton 1980 crop)
.50 gals. ETOH/bu.

Table 14 shows the bushels of each feedstock required to produce 20,000 gallons, 1 million gallons, and 50 million gallons of ethanol. To calculate feedstock cost, these amounts are multiplied by the per unit costs.

Table 14. Annual Feedstock Requirements by Still, in Bushels

	Barley	Corn	Wheat	Potatoes	Sugar Beets
Farm Still	12,195	9,250	9,709	22,472	34,483
Community/ Co-op Still	609,756	462,963	480,770	1,123,596	1,724,138
Commercial Still	30,487,805	23,148,149	24,038,462	56,179,776	86,206,897

Total Ethanol Still Production Costs

Table 15 summarizes production costs by feedstock for each size still. All fixed, operating, and feedstock costs are included.

The cost of ethanol production ranges from $1.86 per gallon for the commercial still using sugar beets to $3.91 per gallon for the farm still using potatoes.

Costs of production for the farm still range from $3.39 to $3.91 per gallon from different feedstocks. Automation of this still shifts labor costs to capital cost, which is amortized over 10 years. The original capital cost is increased 58 percent, from $44,000 to $79,500, but $25,500 is saved in labor each year. Cost of production for the automated farm still ranges from $2.31 to $2.83 per gallon, depending upon feedstock used.

Table 15. Ethanol Still Csots by Feedstock

	Barley ($2.46/bu)		Corn ($.50/bu)		Wheat ($3.55/bu)		Potatoes ($59/tn)		Sugar Beets ($33/tn)	
	Total Cost	Cost per Gal.	Ttotal Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.
	DOLLARS									
1. Farm Still (20,000 gal/yr)										
Fixed Costs										
Depreciation	4,400	.22	4,400	.22	4,400	.22	4,400	.22	4,400	.22
Interest	2,200	.11	2,200	.11	2,200	.11	2,200	.11	2,200	.11
Insurance, Taxes, & Permits	400	.02	400	.02	400	.02	400	.02	400	.02
SUBTOTAL	7,500	.35	7,000	.35	7,000	.35	7,000	.35	7,000	.35
Operating Costs										
Labor	27,200	1.36	27,200	1.36	27,200	1.36	27,200	1.36	27,200	1.36
Fuel	1,800	.09	1,800	.09	1,800	.09	1,800	.09	1,800	.09
Electricity	300	.02	300	.02	300	.02	300	.02	300	.02
Maintenance & Repair	1,760	.09	1,760	.09	1,760	.09	1,760	.09	1,760	.09
Miscellaneous	500	.02	500	.02	500	.02	500	.02	500	.02
SUBTOTAL	31,560	1.58	31,560	1.58	31,560	1.58	31,560	1.58	31,560	1.58
Feedstock	29,999	1.49	32,407	1.61	34,466	1.72	39,775	1.98	29,310	1.46
TOTAL	68,559	3.42	70,967	3.54	73,026	3.65	78,335	3.91	67,870	3.39

Table 15. (continued)

	Barley ($2.46/bu)		Corn ($.50/bu)		Wheat ($3.55/bu)		Potatoes ($59/tn)		Sugar Beets ($33/tn)	
	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.
	DOLLARS									
2. Automated Farm Still (20,000 gal/yr)										
Fixed Costs										
Depreciation	6,950	.35	6,950	.35	6,950	.35	6,950	.35	6,950	.35
Interest	3,475	.17	3,475	.17	3,475	.17	3,475	.17	3,475	.17
Insurance, Taxes, & Permits	400	.02	400	.02	400	.02	400	.02	400	.02
SUBTOTAL	10,825	.54	10,825	.54	10,825	.54	10,825	.54	10,825	.54
Operating Costs										
Labor	1,700	.08	1,700	.08	1,700	.08	1,700	.08	1,700	.08
Fuel	1,800	.09	1,800	.09	1,800	.09	1,800	.09	1,800	.09
Electricity	300	.02	300	.02	300	.02	300	.02	300	.02
Maintenance & Repair	1,760	.09	1,760	.09	1,760	.09	1,760	.09	1,760	.09
Miscellaneous	500	.02	500	.02	500	.02	500	.02	500	.02
SUBTOTAL	6,060	.30	6,060	.30	6,060	.30	6.060	.30	6,060	.30
Feedstock	29,999	1.50	32,407	1.62	34,466	1.72	39,775	1.99	29,310	1.47
TOTAL	46,884	2.34	,292	2.46	51,351	2.57	56,660	2.83	46,195	2.31

Table 15. (continued)

	Barley ($2.46/bu)		Corn ($.50/bu)		Wheat ($3.55/bu)		Potatoes ($59/tn)		Sugar Beets ($33/tn)	
	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.
	DOLLARS									
3. Community/Co-op Still (1,000,000 gal/yr)										
Fixed Costs										
Depreciation	157,000	.15	157,000	.15	157,000	.15	157,000	.15	157,000	.15
Interest	78,750	.08	78,750	.08	78,750	.08	78,750	.08	78,750	.08
Insurance, Taxes, & Permits	20,000	.02	20,000	.02	20,000	.02	20,000	.02	20,000	.02
SUBTOTAL	255,750	.25	255,750	.25	255,750	.25	255,750	.25	255,750	.25
Operating Costs										
Labor	374,960	.38	374,960	.38	374,960	.38	374,960	.38	374,960	.38
Fuel	190,000	.19	190,000	.19	190,000	.19	190,000	.19	190,000	.19
Electricity	10,000	.01	10,000	.01	10,000	.01	10,000	.01	10,000	.01
Maintenance & Repair	63,000	.06	63,000	.06	63,000	.06	63,000	.06	63,000	.06
Miscellaneous	10,000	.01	10,000	.01	10,000	.01	10,000	.01	10,000	.01
SUBTOTAL	647,960	.65	647,960	.65	647,960	.65	647,960	.65	647,960	.65
Feedstock	1,500,000	1.50	1,620,000	1.62	1,706,731	1.71	1,988,764	1.99	1,465,517	1.47
TOTAL	2,403,710	2.40	2,523,710	2.52	2,610,441	2.61	2,892,474	2.81	2,369,227	2.37

Table 15. (continued)

	Barley ($2.46/bu)		Corn ($.50/bu)		Wheat ($3.55/bu)		Potatoes ($59/tn)		Sugar Beets ($33/tn)	
	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.	Total Cost	Cost per Gal.
	DOLLARS									
4. Commercial Still (50,000,000 gal/yr)										
Fixed Costs										
Depreciation	6,365,000	.12	6,365,000	.12	6,365,000	.12	6,365,000	.12	6,365,000	.12
Interest	3,182,500	.06	3,182,500	.06	3,182,500	.06	3,182,500	.06	3,182,500	.06
Insurance, Taxes, & Permits	80,000	.01	80,000	.01	80,000	.01	80,000	.01	80,000	.01
SUBTOTAL	9,627,500	.19	9,627,500	.19	9,627,500	.19	9,627,500	.19	9,627,500	.19
Operating Costs										
Labor	3,880,000	.08	3,880,000	.08	3,880,000	.08	3,880,000	.08	3,880,000	.08
Fuel	3,400,000	.07	3,400,000	.07	3,400,000	.07	3,400,000	.07	3,400,000	.07
Electricity	720,000	.01	720,000	.01	720,000	.01	720,000	.01	720,000	.01
Maintenance & Repair	920,000	.02	920,000	.02	920,000	.02	920,000	.02	920,000	.02
Miscellaneous	1,176,500	.02	1,176,500	.02	1,176,500	.02	1,176,500	.02	1,176,500	.02
SUBTOTAL	10,096,500	.20	10,096,500	.20	10,096,500	.20	10,096,500	.20	10,096,500	.20
Feedstock	75,000,000	1.50	80,018,518	1.60	85,336,538	1.71	98,314,607	1.97	73,275,826	1.86
TOTAL	94,724,000	1.89	99,742,518	1.99	105,060,538	2.10	118,038,607	2.36	92,999,826	1.86

Cost of production for the commercial/co-op still is approximately the same as the automated farm still. It ranges from $2.37 to $2.89 per gallon.

The commercial still, because of economies of size, produces ethanol at the lowest cost, ranging from $1.86 to $2.36 per gallon.

Sensitivity Analysis

The total cost of ethanol production depends on the various costs incurred. Fixed, operating, and feedstock costs all influence the overall cost. Two methods have been used to estimate the impact of individual cost components on total costs. One is to present fixed, operating, and feedstock costs as a percentage of total costs. The second is to vary each of the cost factors and look at its influence on the cost of producing one gallon of alcohol.

Fixed, Operating, and Feedstock Costs as a Percentage of Total Costs

Table 16 presents fixed, operating, and feedstock costs as a percentage of total cost. Corn was selected as a representative feedstock because it is a medium-priced feedstock and is the feedstock most frequently cited in gasohol literature.

Feedstock cost is the major proportion of total cost, and increases as a proportion of the total from the farm still to the commercial still. Feedstock cost is 45.66 percent of total cost for the farm still, 65.75 percent for the automated farm still, 64.2 percent for the community/co-op still, and 80.2 percent for the commercial still.

Operating costs are almost as high, 44.48 percent, for the farm still because of the amount of labor required. Operating costs vary from 10.1 percent to 25.7 percent in the other stills. Fixed costs range from 9.7 to 21.96

Table 16. Fixed, Operating, and Feedstock Costs as a Percentage of Total Costs by Still Size Using Corn Feedstock

Costs	Farm Still		Automated Farm Still		Community/Co-op Still		Commercial Still	
	Cost	Percent of total cost	Cost	Percent of total cost	Cost	Percent of total cost	Cost	Percent of total cost
	($)	(%)	($)	(%)	($)	(%)	($)	(%)
Fixed Costs:								
Depreciation	4,400	6.20	6,950	14.10	157,000	6.2	6,365,000	6.4
Interest	2,200	3.10	3,475	7.05	78,750	3.1	3,182,500	3.2
Insurance, Taxes, and Permits	400	.56	400	.81	20,000	.8	80,000	.1
SUBTOTAL	7,000	9.86	10,825	21.96	255,750	10.1	9,627,500	9.7
Operating Costs:								
Labor	27,200	38.33	1,700	3.45	374,960	14.9	3,880,000	3.9
Fuel	1,800	2.54	1,800	3.65	190,000	7.5	3,400,000	3.4
Electricity	300	.42	300	.61	10,000	.4	720,000	.7
Maintenance and Repair	1,760	2.48	1,760	3.57	63,000	2.5	920,000	.9
Miscellaneous	500	.71	500	1.01	10,000	.4	1,176,500	1.2
SUBTOTAL	31,560	44.48	6,060	12.29	647,960	25.7	10,096,500	10.1
Feedstock:								
Corn	32,407	45.66	32,407	65.75	1,620,370	64.2	80,018,518	80.2
SUBTOTAL	32,407	45.66	32,407	65.75	1,620,370	64.2	80,018,518	80.2
TOTAL	70,967	100.00	49,292	100.00	2,524,080	100.0	99,742,518	100.0

percent. Fixed costs for the automated farm still are the highest because of high capital costs.

Variation in Base Case Parameters

From the base budgets developed using corn as the representative feedstock, each cost item was varied to determine its sensitivity relative to the total production cost of ethanol. Each cost was varied 20 percent, holding all other parameters constant. In addition to explicit cost items, the alcohol conversion, or yield rate, was also included in the cost sensitivity analysis. Table 17 shows the change in base cost per gallon of ethanol when yield, feedstock (corn) cost, capital (fixed) cost, and fuel and electricity costs change 20 percent. Maintenance and repair, as well as miscellaneous costs were not varied because they make up only a small portion of total costs.

Ethanol yield and feedstock cost are the most sensitive parameters. As seen in Table 17, a 20 percent increase in yield reduces the cost of ethanol production $.30, from $1.99 to $1.69 per gallon for the commercial still. A 20 percent decrease in yield increases cost to $2.29 per gallon. Increasing feedstock cost 20 percent increases production costs by $.32, from $1.99 to $2.31 per gallon for the commercial still. The rest of this table is interpreted the same way.

Dividing the change in base cost resulting from a 20 percent change in each parameter, by the base cost for each still, shows the percent change in base cost caused by the 20 percent change. For example, a 20 percent increase in yield decreases commercial still costs $.30 per gallon, a change of 15.08 percent in the base cost of $1.99 per gallon. The percent change in base cost is shown for each parameter in Table 17.

Table 17. Change in Base Costs per Gallon with 20 Percent Changes in Ethanol Yield and Input Costs

	FARM STILL		AUT. FARM STILL		COMM./CO-OP STILL		COMMERCIAL STILL	
	($/gal)	(% Change in base cost)	($/gal)	(% Change in base cost)	($/gal)	(% Change in base cost)	($/gal)	(% Change in base cost)
Base Cost	3.54		2.46		2.52		1.99	
20% Change in Individual Parameters:								
Yields	.330	9.32	.310	12.60	.320	12.70	.300	15.08
Feedstock Costs (corn)	.320	9.04	.320	13.01	.320	12.70	.320	16.08
Labor Costs	.272	7.68	.016	.65	.076	3.02	.015	.75
Capital Costs	.070	1.98	.108	4.39	.050	1.98	.038	1.91
Fuel and Electric Costs	.022	.62	.022	.89	.040	1.59	.016	.80

The percent of total cost by parameter from Table 16 can be compared to the percent change in base cost for each parameter in Table 17. When comparing these two tables it becomes apparent that the effect on base cost caused by a 20 percent change in a parameter is related to that parameter's contribution to total cost.

An 80 percent ethanol yield is assumed in Table 16. Feedstock costs make up a greater percent of total cost as still size increases, changes in feedstock costs, therefore, influence base cost more as still size increases. Labor costs influence base costs of the farm still more than any other still.

Figures 1 through 4 illustrate the effects of input cost and yield variations on the base cost per gallon of ethanol. To interpret these illustrations (using Figure 1 as an example), first locate the intersection of the dashed vertical and horizontal lines. This point ($3.54) defines the base cost per gallon given the input costs and ethanol yield assumed in the development of the farm still budget using corn as a feedstock (refer to Table 15). The sensitivity of ethanol production costs (the vertical axis in Figure 1) to variations in specified input costs or yield is illustrated by the series of diagonal solid lines. The percentage change for a given parameter is selected on the horizontal axis, and the resulting cost given the change is read off of the vertical axis. For example, a 30 percent increase in feedstock cost raises the base cost $.48 to $4.02 per gallon, and a 30 percent decrease reduces it by $.48 to $3.02 per gallon. Increasing any of the 4 cost variables will predictably increase per gallon costs, while increasing yield (productivity) decreases costs, and vice versa. Figures 2 through 4 are interpreted the same way for the other stills.

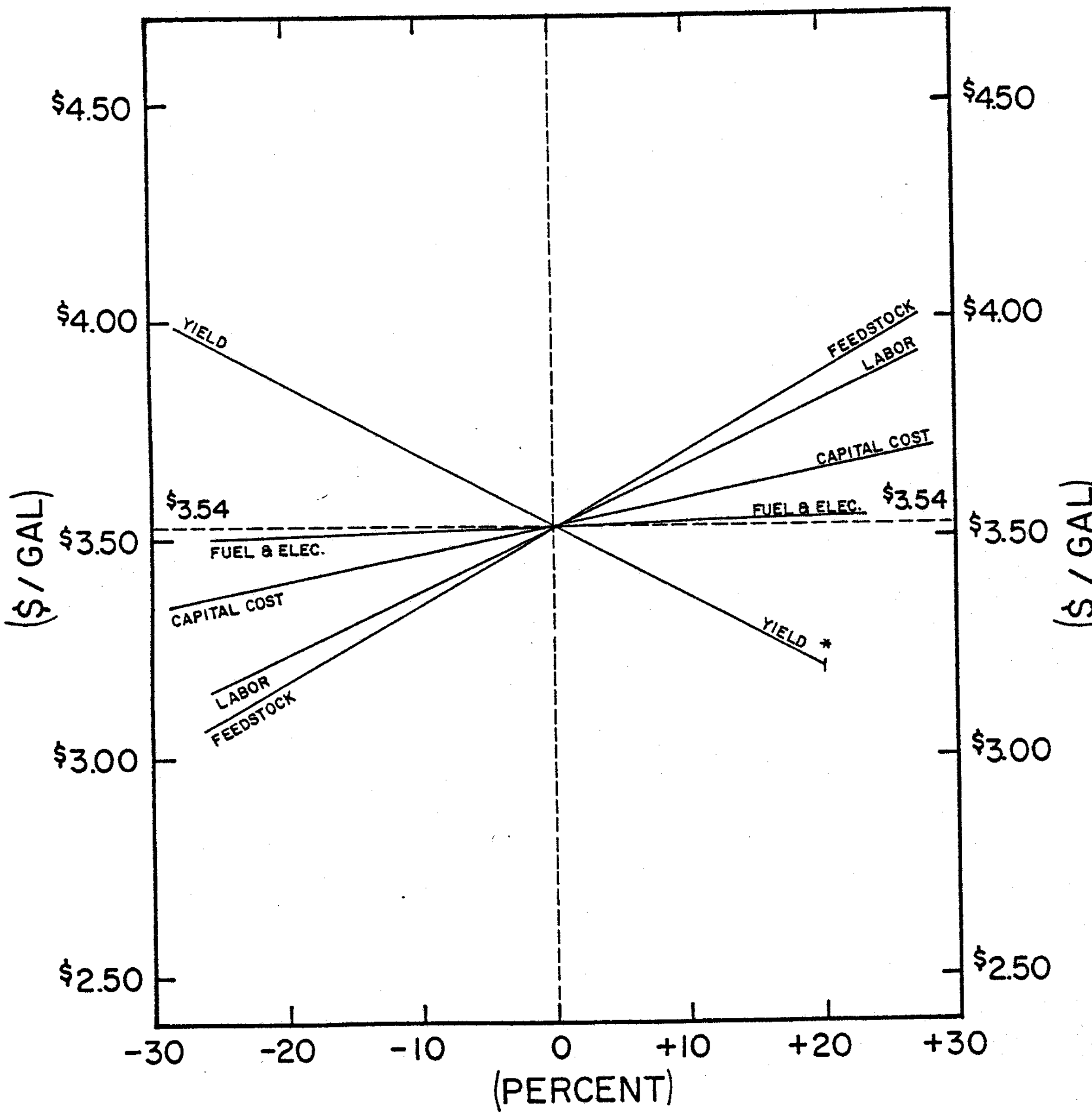

FIG. 1 Percent variation in Base Case Values – 20,000 gallons Farm Still (corn)

* *Maximum theoretical yield*

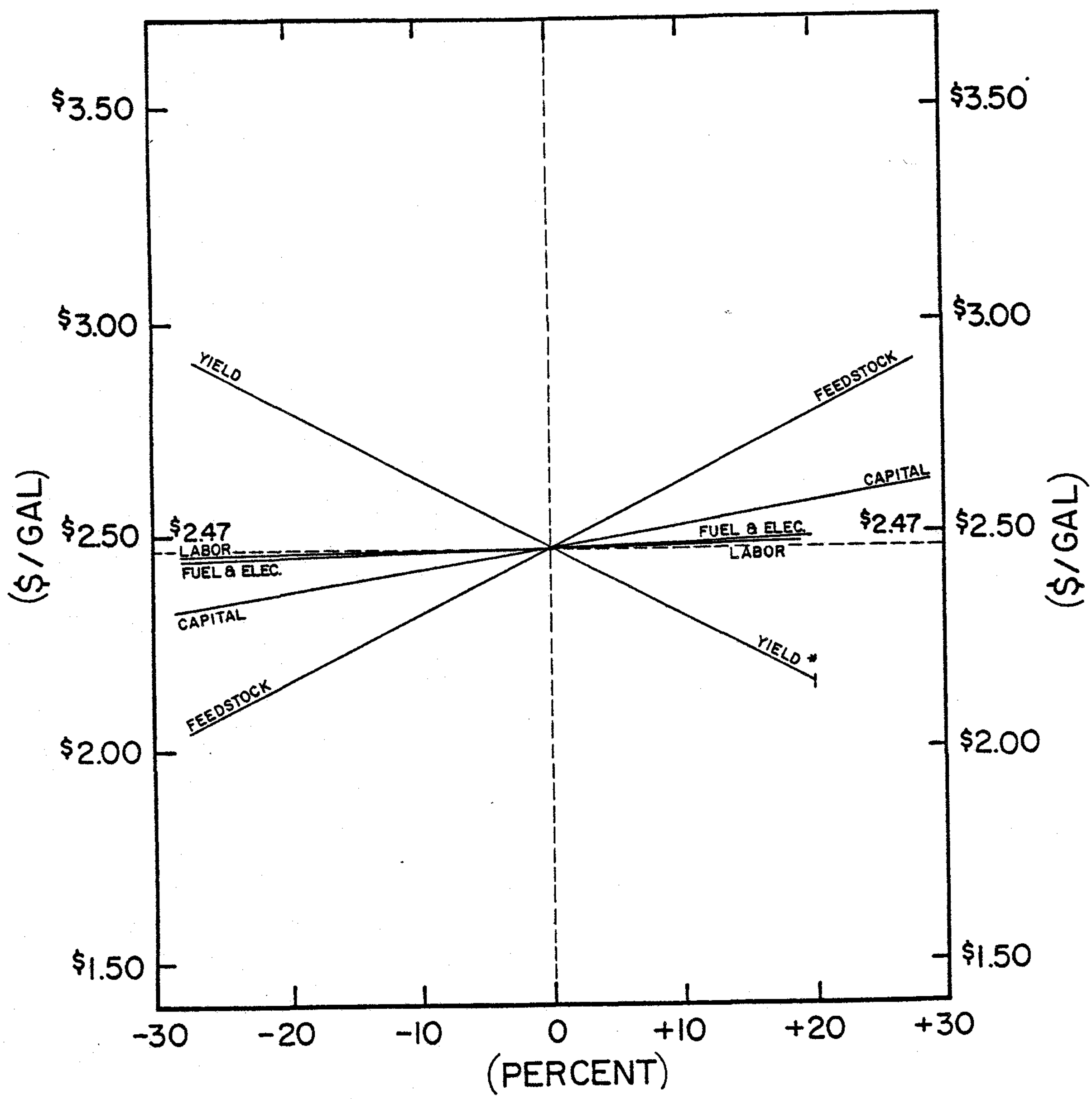

FIG. 2 Percent variation in Base Case Values– Automated Farm Still (corn)

** Maximum theoretical yield*

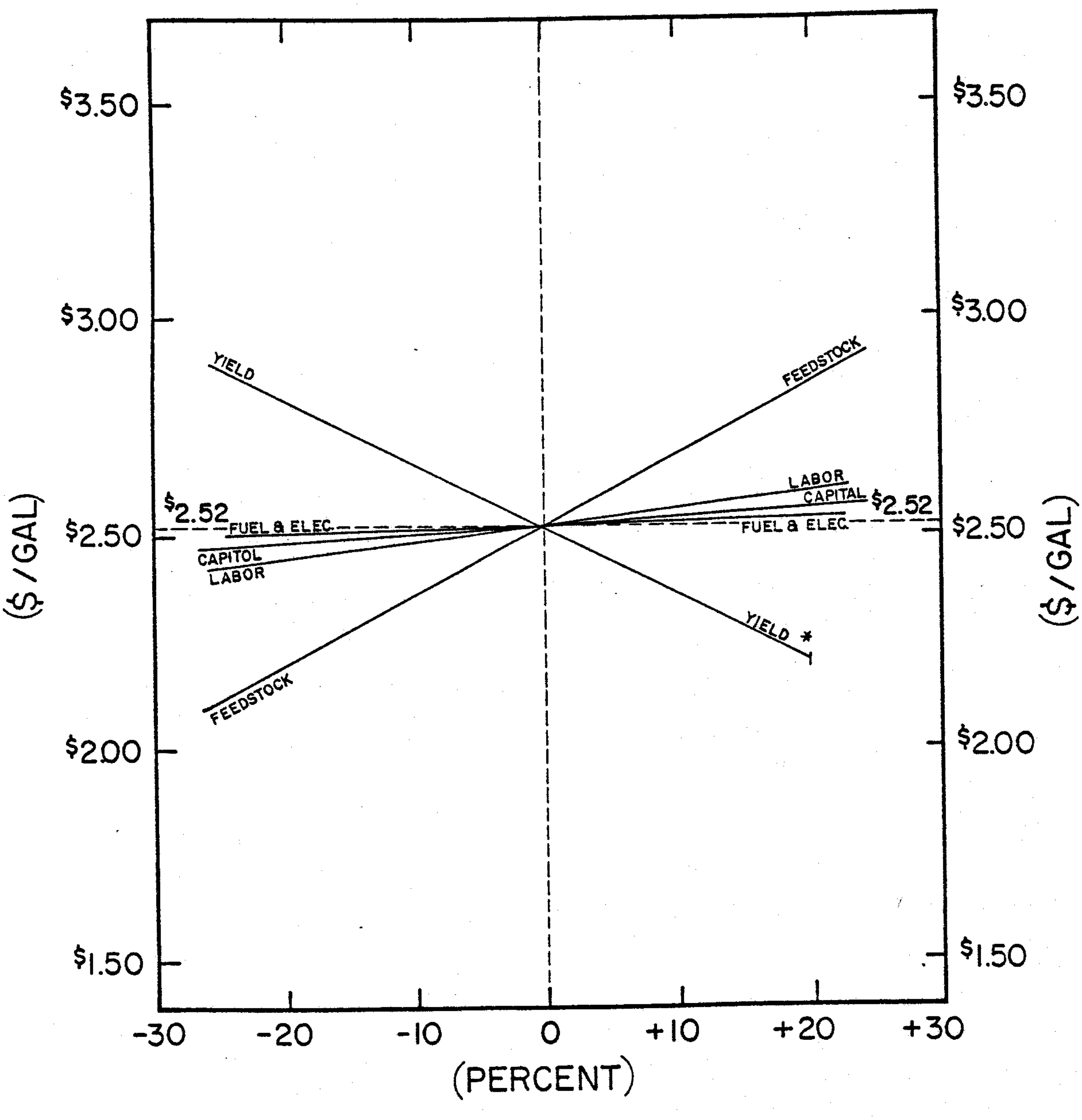

FIG. 3 Variation in Base Case Values – 1 MG Community/ Coop Still

**Yield cannot increase more than 20%*

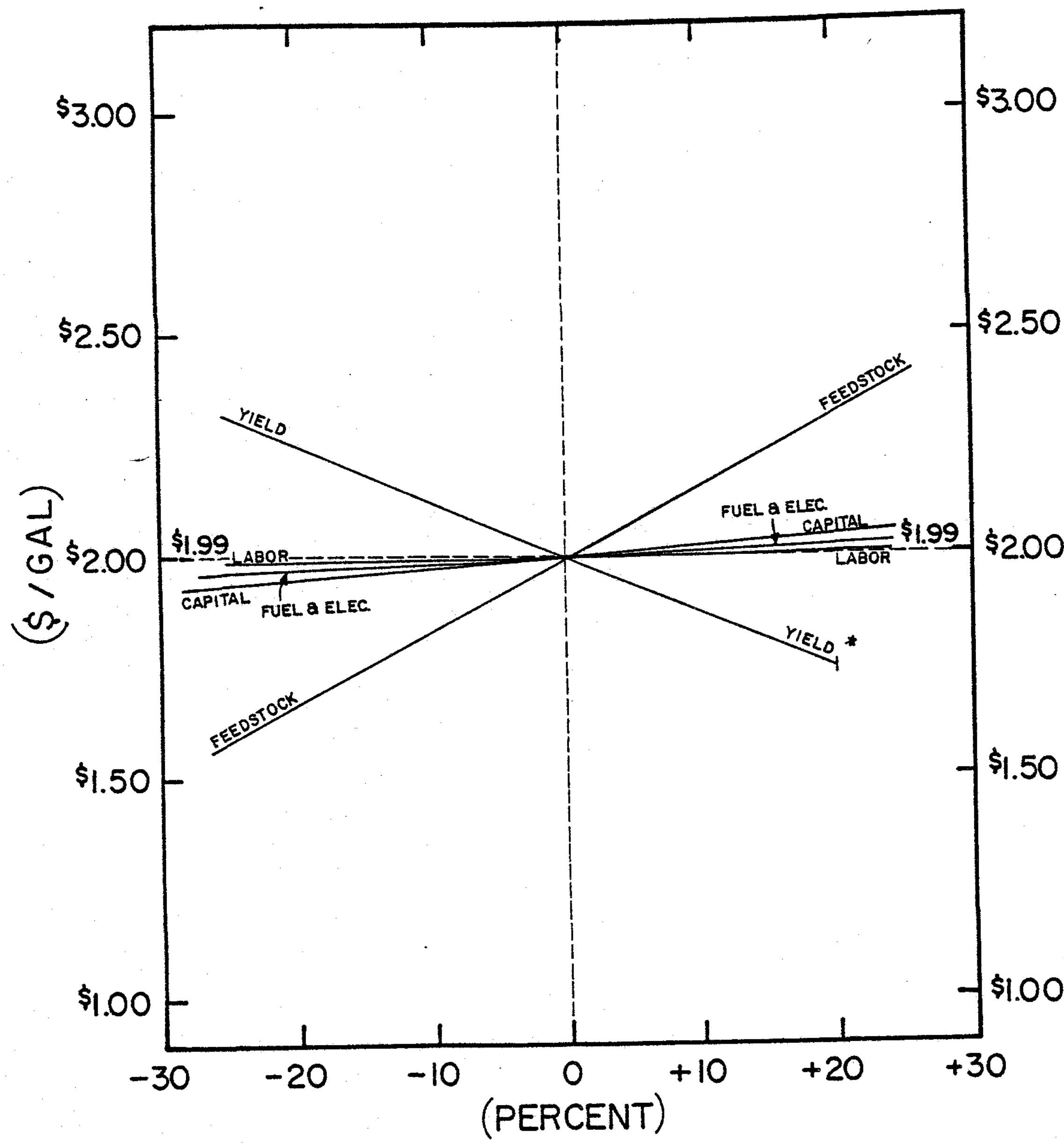

FIG. 4 Percent variation in Base Case Values – 50 M Gallons Still using (corn).

** Maximum theoretical yield*

VI. POTENTIAL MARKETS FOR DISTILLERS' FEEDS IN OREGON

The process of fermenting agricultural biomass results in three major joint products: ethyl alcohol, distillers' feeds, and carbon dioxide. The use and value of these joint products ultimately affect the economic feasibility of alcohol production from agricultural feedstocks. For example, one bushel of grain (60 pounds) yields 20 pounds of dry weight distillers' feeds, 20 pounds of ethanol, and 20 pounds carbon dioxide and water produced in the fermentation process [Kienholz].

The cost of capturing the carbon dioxide from alcohol production and transforming it into liquid or dry ice is technically feasible, but economically questionable [Litterman, Eidman, and Jensen]. The potential for marketing distillers' feeds may be more economically viable at the present time and is evaluated here.

The Nature of Distillers' Feeds

The term distillers' feeds (DF) is a comprehensive term for any fermentation co-product with potential feeding qualities. Subcategories of DF include such things as distillers' potato feed, and distillers' dried grains and solubles.

The nutrient content of DF is closely related to the composition of the agricultural biomass feedstock used in the fermentation process. Because a concentration of all nutrients except starch and sugar takes place, the composition of the spent stillage can be calculated with reasonable accuracy if the nutrient content of the feedstock that made up the mash and the conversion rate are known. The concentration of protein in DF makes them useful as protein feeds. They also may be rich in water-soluble vitamins and some minerals.

Much of the research evaluating DF for livestock has been generated by the beverage distilling industry and relates to residues from fermentation of corn, milo, wheat, and rye, with corn and milo being the most frequently evaluated grains. Information on the value of feeds from the fermentation of cull potatoes and sugar beets is limited.[8/] Information on the composition of distillers' feeds presented in Table 18 was developed to guide the formulation of livestock feed rations.

Table 18. Typical Nutrient Composition of Selected Distillers' Feeds

	Wheat		Barley	Corn			Potatoes
	DDG	DDGS	DDG	DDG	DDS	DDGS	D.D. Residue
	%	%	%	%	%	%	%
Dry Matter	93.4	92.5	92.0	93.8	93.3	92.5	95.7
Ash	3.0	4.1	1.8	2.2	7.5	4.6	6.7
Crude Fiber	12.7	9.8	10.1	12.6	3.6	9.1	20.6
Ether Extract	5.9	6.3	11.6	9.3	9.3	10.3	3.1
N-Free Extract	40.4	40.3	40.8	41.9	43.6	41.4	42.4
Protein (N x 6.25)	31.3	32.0	27.7	27.8	29.4	27.0	22.9
Energy: Cattle TDN	73.6	75.2	63.6	79.0	80.3	80.2	61.0
Sheep TDN	77.7	78.5	65.1	76.6	84.0	69.4	61.8
Swine TDN	84.1	85.2	67.7	92.5	79.7	94.3	74.6

SOURCE: National Academy of Science. Atlas of Nutritional Data on United States and Canadian Feeds, 1971.

During the alcohol production process, the fermented grain plus yeast and water are transferred from the fermentor to the still where the alcohol is removed. The material remaining, referred to as whole stillage, ranges from 3 to 10 percent dry matter (DM). The whole stillage has been fed to livestock with varying success. The high water content presents problems in livestock intake, transport, and storage. Coarse, unfermented grains can be removed

8/ A commercial alcohol conversion plant in Washington using potatoes as a feedstock reports a 24 percent crude protein content in the distillers' dried potato residue.

from the whole stillage with a screen and press or centrifuge. These grains range from 60 to 70 percent DM depending on the process used. The thin stillage which contains the yeast cells and other soluble nutrients can then be condensed by an evaporator. About 40 percent of the recovered dry matter is solubles and 60 percent is dried grains. Condensed solubles range in DM content from 20 to 40 percent. These solubles are dried back onto the grains, but there is potential for using the condensed solubles in liquid supplements because of the high prosphorus and nitrogen content.

The four primary by-products are defined as follows:

Distillers' Dried Grains with Solubles (DDGS) is the product obtained after ethyl alcohol is removed (distilled) from the yeast fermentation of grain or, more generally, biomass, followed by condensing (drying) at least three-fourths of the solids of the whole stillage.

Distillers' Dried Grains (DDG) are obtained by separating and drying the coarse grain fraction of the whole stillage.

Distillers' Dried Solubles (DDS) are obtained by condensing the liquid stillage fraction and drying it.

Distillers' Condensed Solubles (DCS) are obtained after condensing the liquid stillage fraction to a semi-solid.

Distillers' grains have a high level of fiber. For this reason, distillers' grains have limited use in monogastric growing rations (swine and poultry), although they have a potential use in the breeder herd and layer type rations of these livestock groups. Research suggests a limit for the maximum level of distillers' grains in most rations is 20 to 25 percent of total dry matter intake [Kienholz 1979]. Exceptions to the 20 to 25 percent limit would be lactating dairy cow and breeding sow rations (30 to 35 percent), and growing swine and poultry rations (0 percent).

Distillers' feeds can be stored for long periods after drying to a moisture content of between 8 and 12 percent. If stored in bulk, occasional moving or circulation is recommended to prevent formation of high moisture areas (spoilage). Heating and mold damage can occur if the moisture content reaches or exceeds 16 percent of total DDGS weight.

Dried distillers' solubles (DDS) are packaged in moisture-proof bags because of hygroscopic tendencies. When uniformly dried to 5 percent moisture and stored in a dry, cool location, the product can be kept for long periods and remain stable and free flowing.

Feeding DDG, DDGS, or DDS presents no problems with grain storage and distribution. Distillers' dried solubles or distillers' condensed solubles is used for liquid supplements; DDG and DDGS are handled similarly to other protein feeds such as soybean meal.

There is limited information on feeding wet distillers' grains. The nutritional value probably is similar to dry grains. Handling wet grains eliminates the cost of installing and operating drying equipment. However, storage facilities may be a problem since wet grains tend to spoil rapidly. Distillers' feeds in wet form could be fed either as slop or in centrifuge form (about 30 percent DM). The thin stillage from the centrifuge could be recycled through the fermentation system.

The most feasible livestock groups for using wet DF are feedlot cattle, and possibly dairy cattle. Whole stillage can be fed to cattle but reduced performance may result because of the large amounts of water consumed to obtain the desired nutrients. Feeding of whole stillage also may require disposal of a greater volume of animal wastes [Poos and Klopfenstien].

If a beef feedlot is close to an alcohol plant, wet grains can be pumped and distributed in feed troughs by pneumatic-type feed trucks. The wet grain also could be trucked to nearby feedlots, although cost of transporting such a bulky, perishable product would restict such movement.

Potential Use of Distillers' Feeds in Livestock Rations

Beef, dairy, and poultry growers are potential users of DF. Their demand varies depending on the particular DF under consideration and its price relative to substitute feeds. Oregon dairy cow, beef cattle, hog, and sheep numbers are listed in Table 19.

Table 19. Oregon Livestock and Poultry Inventory (thousands)

	1975	1976	1977	1978	1979	Average
Dairy Cows	91	92	93	93	93	92.2
Beef Cattle	709	638	607	622	597	634.6
Hogs	95	95	95	100	100	97.0
Sheep	415	420	395	410	460	420.0
Laying Hens	2,894	2,850	2,800	2,800	2,900	2,848.8
Broilers	14,000	15,200	15,600	15,000	17,300	15,520.0
Turkey Breeder Hens	70	60	45	63	74	62.4
Roaster Turkeys	1,075	1,300	1,350	1,275	1,265	1,253.0

Cattle feedlots in Oregon also are potential users of DF. As demonstrated in Table 20, the total number of cattle on feed has declined from a high in 1977 of 195,000 head to 147,000 in 1979.

Table 20. Oregon Cattle on Feed (1,000 Head)

	-----------Quarterly Placements on Feed---------				
	Jan.-March	April-June	July-Sept.	Oct.-Dec.	Total
1975	32	32	55	51	170
1976	42	36	43	55	176
1977	39	45	50	61	195
1978	36	42	43	47	168
1979	32	31	36	48	147

SOURCE: USDA, Cattle on Feed Crop Reporting Board, ESCS, Washington, D.C.

Beef Cattle

Cattle feeding, rather than cow-calf grazing operations, offers the greatest potential for utilizing DF because high levels of concentrate feed are used.

Beef cattle typically are fed a mixture of concentrates and roughages. The roughages usually are silage and hay, fed with grains and protein supplements. As the animal gains weight, the proportion of concentrates in the ration is increased until slaughter weight is reached. The cost of protein supplements is often a major portion of total costs in cattle feeding operations.

Cattle can synthesize microbial protein from the ammonia generated by the breakdown of feed proteins by rumen micro-organisms. Because ruminants have this ability to convert feed nitrogen to microbial protein, in some cases a lower quality protein source can be fed. An example is the use of nonprotein nitrogen sources, such as urea, in cattle feeds.

Animal scientists at the University of Nebraska have evaluated distillers' grains as protein sources for beef cattle [Poos and Klopfenstein]. They tested the theory that protein from distillers' grain would be worth more than soybean meal (SBM) because the protein in distillers' grains resists breakdown by rumen micro-organisms; that is, some of the protein from distillers' grains might be replaced with urea without depressing animal performance. The effects of four protein supplements--SBM, urea, urea plus DDG, and urea plus DDGS--on average daily gain (ADG) and feed efficiency are shown in Table 21. Rate of gain with distillers' grains plus urea was not much better than urea alone. Feed efficiency was nearly as good as with SBM but, since half of the distillers' grain protein had been replaced with urea, considerable economic savings were realized.

Another experiment by the Nebraska scientists provided a comparison of distillers' dried grains with solubles as sources of low solubility proteins.

Low solubility means the proteins are not easily broken down by rumen microorganisms. They found that the drying process apparently reduces degradation in the rumen of the protein in distillers' solubles which may be of some advantage to the animal. However, distillers' dried grains appear to give a better complementary effect with urea than distillers' dried grains with solubles. In addition, condensed distillers' solubles may be readily utilized in liquid supplement formulation [Beeson]. From both a nutritional and protein utilization standpoint, it may be useful for an alcohol production plant to supply condensed distillers' solubles and distillers' dried grains separately rather than as DDGS.

Diary Cattle

Typical components of dairy cow feed rations are alfalfa hay, corn silage, grain, and protein supplements. High-producing dairy cows have a high protein requirement, especially during early lactation (as high as 18 percent crude protein in the ration dry matter). The bacterial protein synthesized in the cow's rumen provides only a small portion of the total protein requirement. It is necessary to have a high proportion of the feed protein escape breakdown and

Table 21. Feedlot Performance of Calves Fed Distillers' Feeds and Urea as Supplemental Nitrogen Sources[a/]

Item	SBM	Urea	Urea[b/] + DDG	Urea[b/] + DDGS
Ave. Daily Grain (lb.)	2.24	1.87	1.92	1.90
Ave. Daily Feed (lb.)	16.40	16.10	14.40	15.50
Feed per lb. of Grain	7.32	8.61	7.50	8.16

[a/] Trial lasted 112 days, 5 individually fed calves per treatment.

[b/] Urea supplied 50 percent of the supplemental nitrogen.

SOURCE: Klopfenstein, Rounds, and Weller, "Distillers' Feeds as Protein Sources for Beef Cattle," Proc. Distillers' Feed Conference, 1976.

pass through the rumen to the small intestine to be further digested. By feeding slowly degraded protein sources, such as distillers' grains, it should be possible to obtain more production from the same amount of protein or the same production with a smaller amount of protein [Poos and Klopfenstein].[9/]

A study of the influence of feeding corn distillers' grains on milk production indicated that an increase in production was obtained when distillers' grains were fed compared with other protein supplements [Warner]. Distillers' grains have an additional value for dairy cattle. Because of the fat and fiber content of these grains, feeding them to high-producing cows prevents the depression in milk fat percentages that often occur when high grain rations are fed to meet the cow's energy requirement. Distillers' grains also have been shown to maintain fat tests better than corn grain in pelleted grain mixtures.

Poultry

The major components of poultry production are egg layer enterprises and broiler growing units. DDGS is not recommended in growing diets for poultry because of the high fiber content. Because of this, attention is devoted to the potential for utilizing DF in rations for laying hens.

Layers require rations consisting of 15 percent protein, according to the National Research Council [Kienholz]. These rations are high in concentrates with little roughage, such as corn. Protein supplements are usually soybean meal and animal by-products. Distillers' feeds could be fed at up to 20 percent of the ration for layers on a dry matter basis [Kienholz et al, 1979].

9/ This increase in efficiency occurs only when DDG and urea are used in a combination that allows microbial protein and bypass DDG protein to complement each other in the small intestine.

Hogs

Distillers' feeds are not recommended as growing rations for pigs, with the possible exception of feeding dried solubles as a vitamin B and phosphorus source, however, further research is needed to verify this. Breeding stock can utilize DDGS at up to one-third of their diet based on present research [Kienholz et al, 1979].

Estimated Value of Distillers' Feeds in Livestock Rations

There is a strong interest in DF, but an accurate assessment of their feeding qualities is difficult to ascertain. Animal scientists do not even agree on information on corn DDGS, the most available distillers' grain. The type and quality of the feedstock affect the nutritional value of the DF, and large combinations of feed are available.

This does not mean that a meaningful framework for economic analysis cannot be formulated. The physical and nutritional characteristics of a DF and prices for close substitutes determine its value as a commercial feed. If a DF can substitute for the protein and other nutrients of another feed (e.g., soybean meal), then it is of interest to determine at what price DF become competitive with the soybean meal.

It is not only important to know if a DF will compete with other feeds, but also how much of it will be demanded at different prices. It is conceivable that little DF would be competitive at high prices, but as its relative price drops, more would be substituted. At very low prices, the nutritional feeding qualities of DF will limit the quantity substituted.

Price Relationships Over Time

Most DF is used as a protein supplement. Price correlations with competitive protein supplements, such as soybean meal, may be used to roughly approximate market value based on relative crude protein content (Table 22). Over time, however, this relationship has not proven particularly reliable. Variations in the price of soybean meal, using Chicago prices for both distillers' dried grains and 44 percent soybean meals, have explained only slightly more than 50 percent of the variation in the price of distillers' grains. Moreover, correlations based purely on protein content ignore several digestive and nutritional issues in animal health, some of which were discussed earlier.

Table 22. Prices for Soybean Meal and Distillers' Dried Grains, Chicago and Portland, 1974-80

Year (Week)	Chicago			Portland
	SBM	DDGS	DDGS/SBM	SBM
	($/Ton)	($/Ton)	(%)	($/Ton)
1973-74	153.50	118.50	77	176.30
1974-75	139.10	111.90	80	164.40
1975-76	157.25	118.70	76	180.25
1976-77	210.10	138.60	66	234.00
1977-78	175.20	117.10	67	197.60
1979 (5/8)	197.20	141.00	72	226.50
1979 (11/14)	193.70	158.20	82	229.90
1980 (4/22)	168.40	143.50	85	208.60
Average			76	

SOURCE: Agricultural Marketing Service, USDA, Feed Market News, Washington, D.C., various issues.

Price/Quantity Schedules

To more closely estimate the market value of DF, a least-cost ration computer program was employed to simulate various DF in competition with a variety of livestock feeds. Typical feeds (soybean meal, corn silage, corn, barley, hay, and feed supplements) were entered into a ration analysis at their market prices. Distillers' feed products were then entered into a computer least-cost ration analysis (described below) at varying price levels to trace the value of marginal product for the DF.

The major objective of the program is to find the combination of chosen feeds meeting the nutritional requirements of a given ration at least cost. Chosen feeds are programmed with their corresponding nutritional analysis. and prices. The program then chooses among the available feeds to meet the ration requirements at least cost. The linear program indicates the shadow prices of the resources used, that is, the price at which more of one resource (feed) would be utilized in the ration. By holding all feed prices constant except the DF price, the quantities and corresponding prices of the DF can be found as it enters the feed ration.

The nutrient and quality analysis of the feed ration is based on minimum or maximum pounds per day of a total dry matter requirement. For example, one feeder ration requires 15.5 pounds of dry matter fed per day with specific minimum and maximum specifications in the following categories:

Minimum Requirement:

crude protein	net energy maintenance	net energy growth
total digestible nutrients	calcium	phosphorus
potassium	magnesium	roughage

Maximum Requirements:

dust urea animal fat

Distillers' dried grains, corn, DDGS wheat, wet wheat stillage, and distillers' dried potatoes (DDP) were programmed to compete with the following feeds?[10/]

[10/] Feed values for DDG corn, DDGS wheat, wet wheat stillage and DDP were obtained from the <u>Atlas of Nutritional Feeds</u>, animal nutritionists at Oregon State University, and information supplied by ethanol plants in operation.

Beef Rations

Feed	Price
Soybean meal	$250/ton
Grass hay	$ 60/ton
Corn	$3.33/bu
Barley	$3.12/bu
Corn silage	$ 25/ton

Dairy Ration

Feed	Price
Soybean meal	$250/ton
Alfalfa hay	$120/ton
Corn	$3.33/bu
Barley	$3.12/bu
Corn silage	$ 25/ton

Rations were formulated for three livestock categories: 1) a beef cattle growing ration (1.5 to 2 pounds average daily gain for 500- to 700-pound steers and heifers); 2) a two-to-three week finishing ration for feedlot steers and heifers; and 3) a dairy ration for high producers of 65 pounds or more of milk per day.

The resulting value of marginal product schedule is analogous to a demand curve, thus, the price-quantity relationships provide insight into potential markets for DF.

The schedules are plotted (Figures 5 through 9) and summarized in terms of their price-quantity relationships (Table 23). The "high" price range illustrates price at which DF first become economically feasible in the ration. None of the DF would be used above this price, given the values of alternative feeds. The "sensitive" price is a normative estimate of the price range over which use of DF appears most responsive to price (i.e., the range of most elastic demand). The "low" price is the range over which further price reductions in DF result in no increased use of them in the ration. This occurs because some quantity of DF exceeds a physical feeding quantity constraint in the feed model.

Some tentatvie conclusions can be drawn regarding the estimated market values of DF. First, the "sensitive" price range often is considerably below the high price at which the feed first entered the ration. Although relatively small amounts of the various DF would be used at the high price levels,

Table 23. Demand Estimates for Selected Distillers' Feeds in Dairy and Beef Rations

Ration	DDG Corn	DDGS Wheat	Wheat Stillage	Distillers' Dried Potatoes
	($/Ton)			
Dairy				
High Price	190	196	28	117
Sensitive Price Range	137-190	75-190	14-27	55-117
Low Price	136	37	14	40
Finishing				
High Price	180	187	6	155
Sensitive Price Range	110-170	95-100	5-6	95-100
Low Price	100	95	5	95
Feeder				
High Price	165	195	15	145
Sensitive Price Range	55-90	55-70	5-15	60-90
Low Price	55	55	5	55

portions (as much as one-half of the entire feeding ration) appear economically feasible at the lower ends of the "sensitive" price ranges. These are economic inferences and do not reflect actual feeding trial results. Further research is required to determine if the economic limits of DF use are practical in feed rations.

A second generalization can be drawn; the value of DF varies significantly between livestock groups. The highest value for DF appears to be in dairy rations, followed by finishing rations, and feeder rations.

The price-quantity relationships compiled above are on an "as fed" basis. As a result, the associated marketing costs such as transportation, distribution, storage, packaging, and handling are reflected in DF prices. Prices received at the originating alcohol plant would be adjusted downward accordingly.

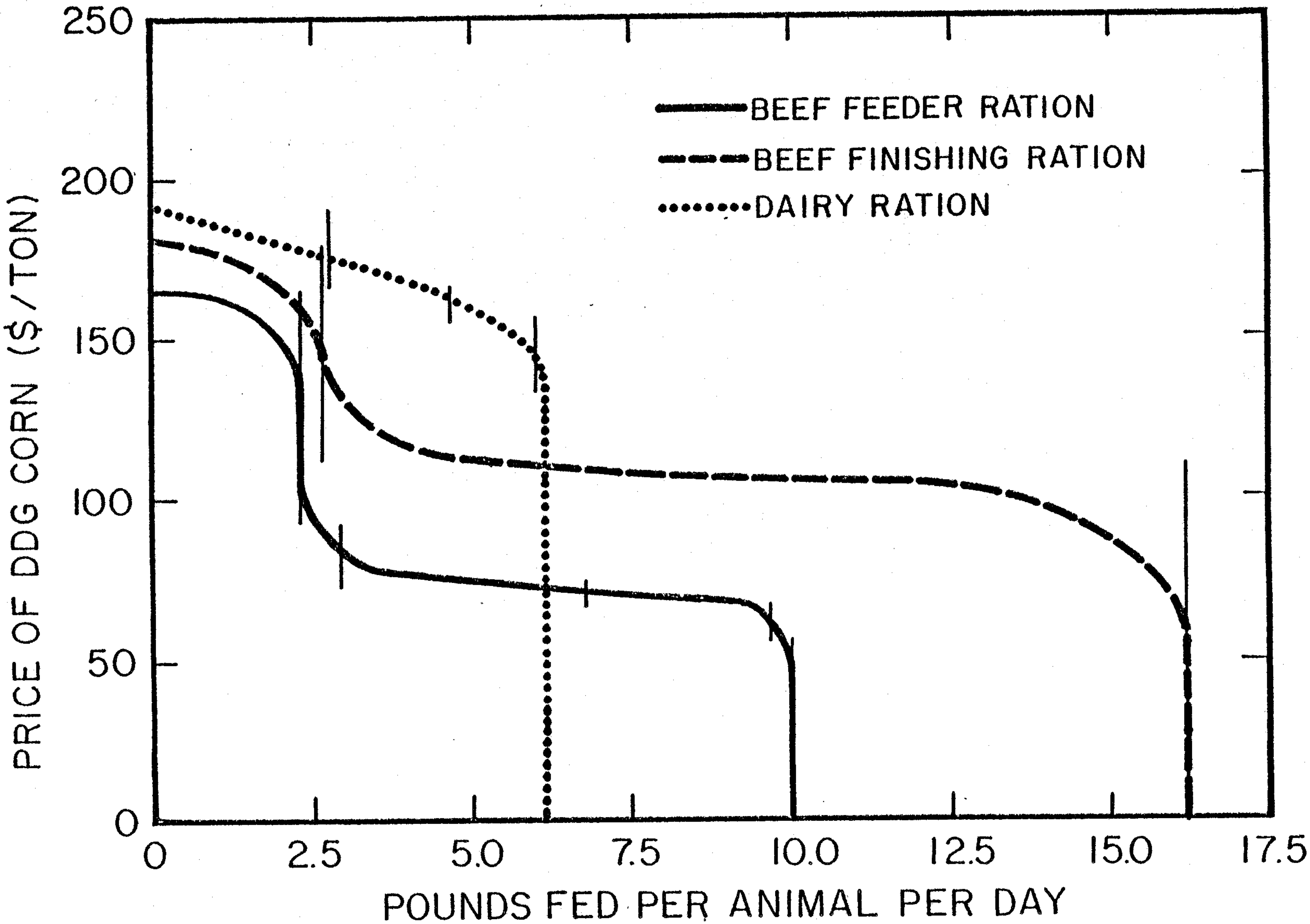

FIG. 5 DEMAND FOR DDG CORN

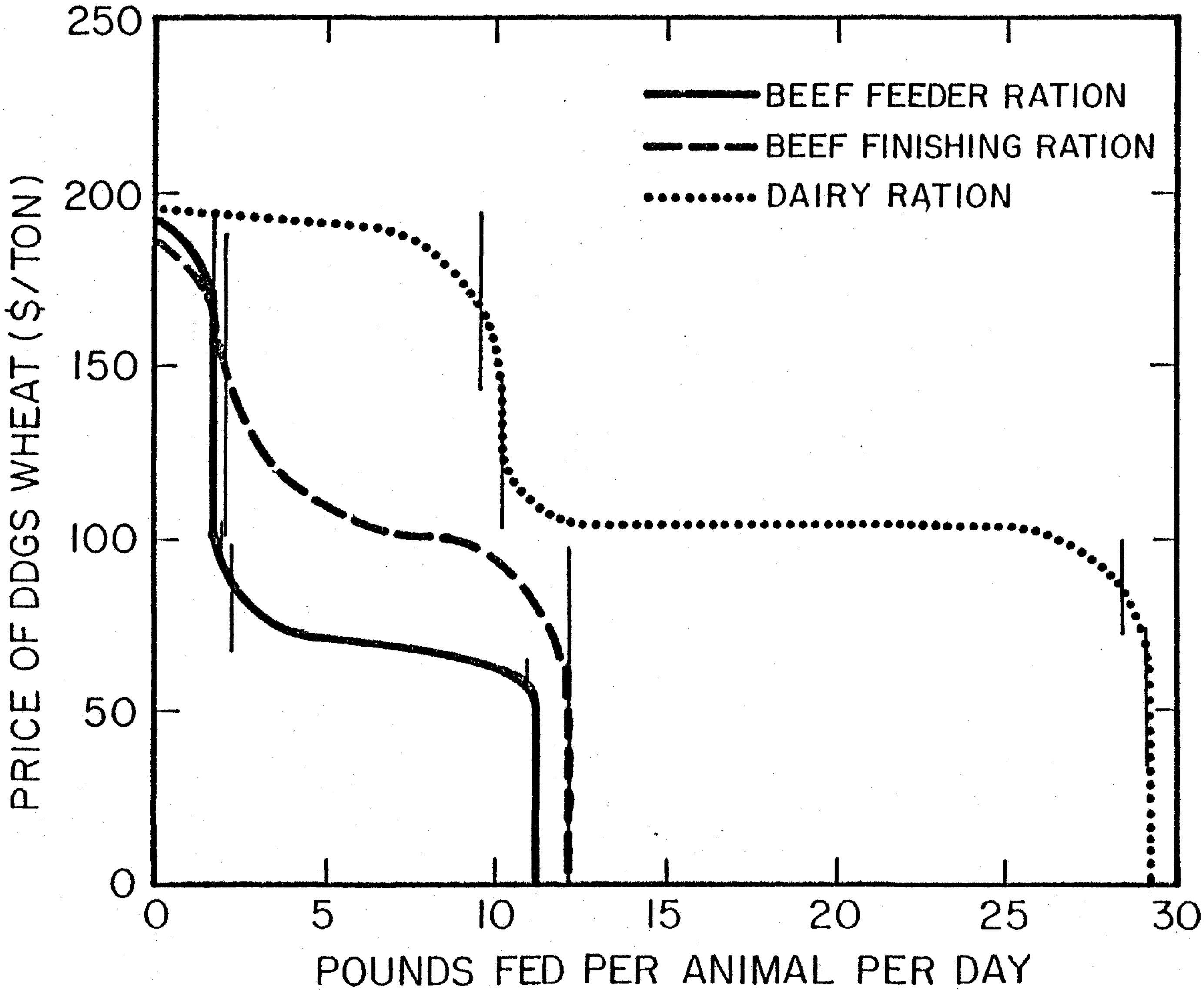

FIG. 6 DEMAND FOR DDGS WHEAT

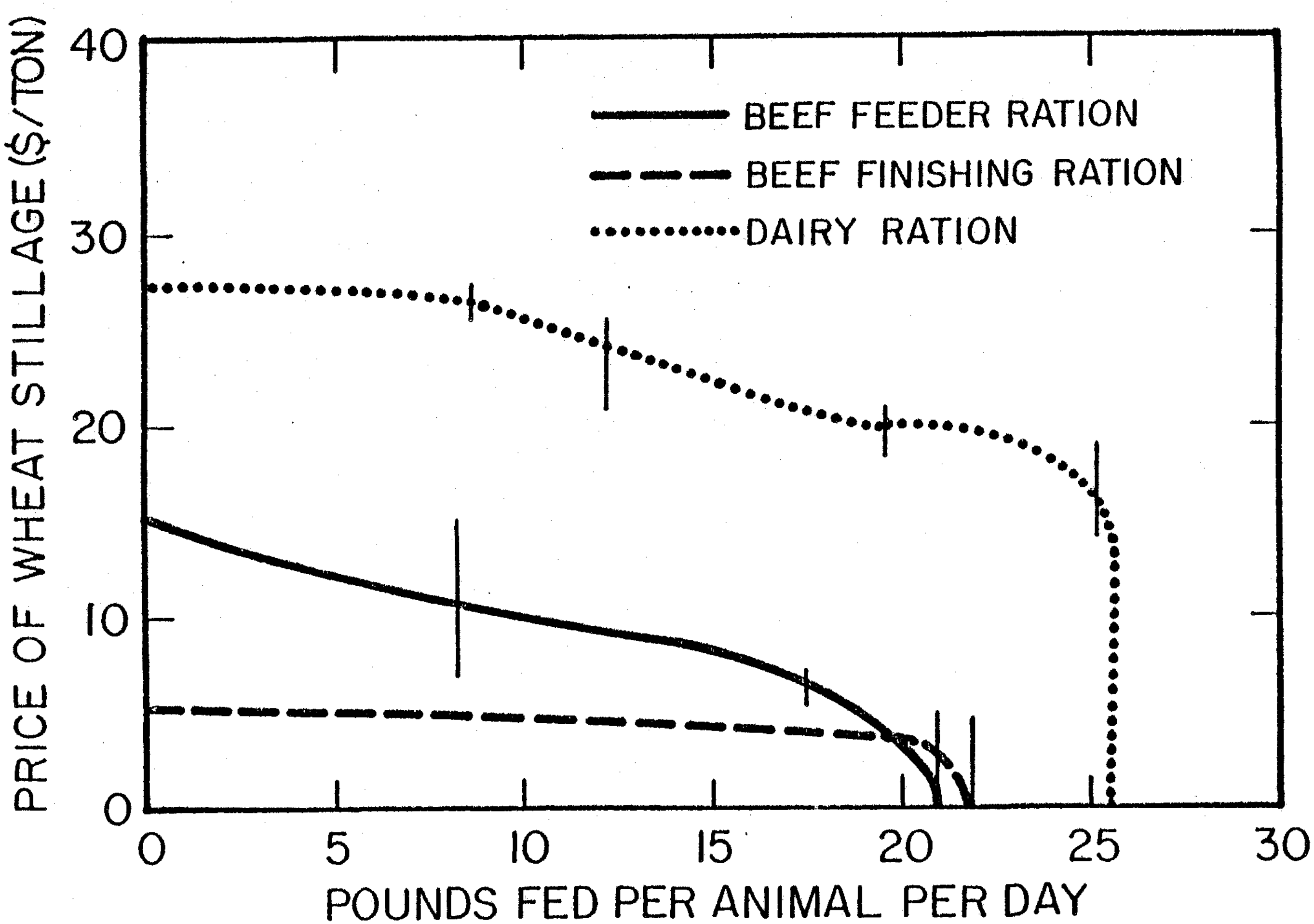

FIG. 7 DEMAND FOR WHEAT STILLAGE

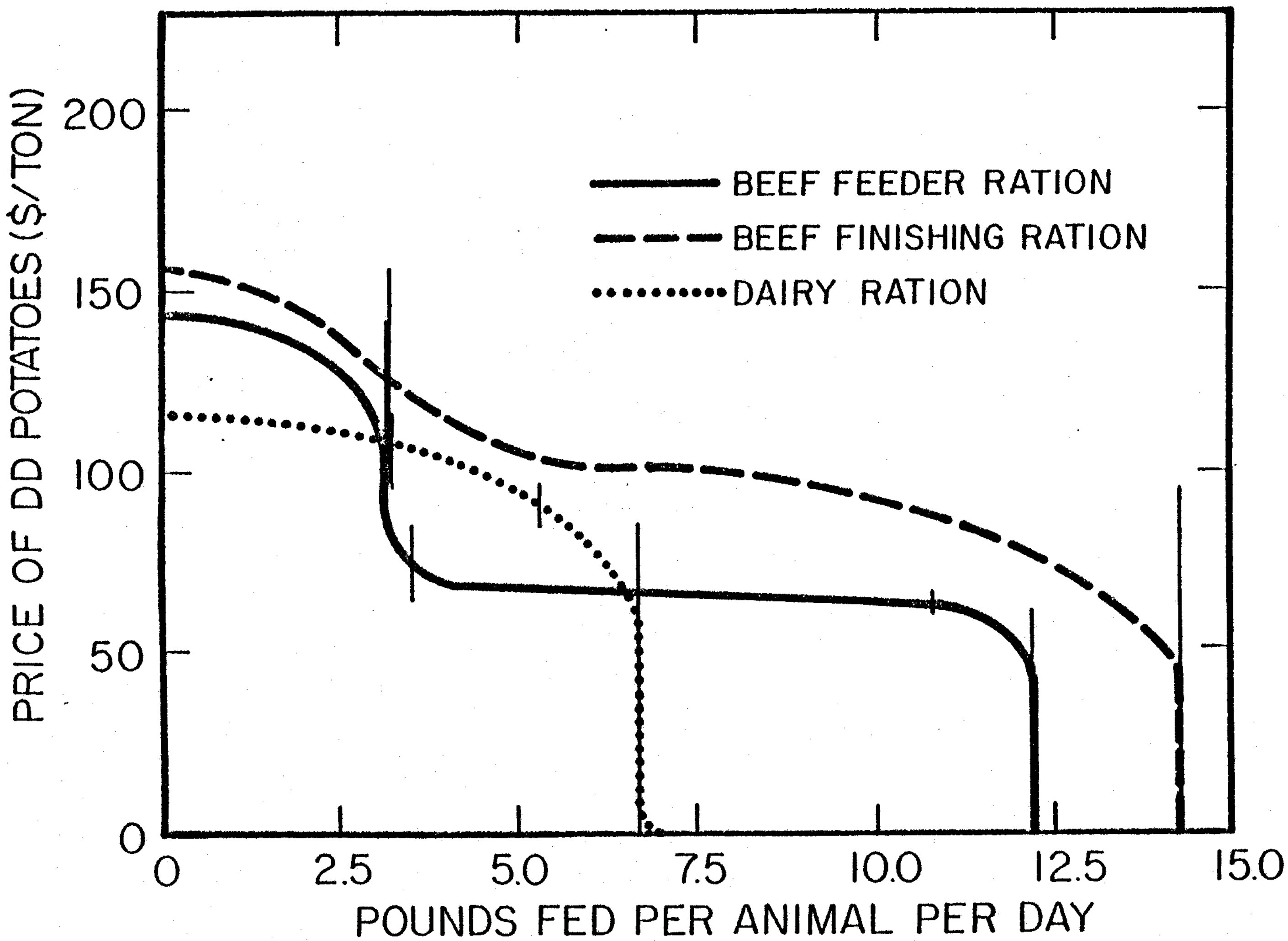

FIG. 8 DEMAND FOR DD POTATOES

Potential Distillers' Feeds Use and Alcohol Equivalents in Oregon

The price-consumption relationships for DF use are summarized in Tables 24, 25, 26, and 27. Indicated use of distillers' feed ranged from less than one percent of the total dry weight to more than 65 percent depending on the ration and the price. The price-consumption data were then correlated with the number of cattle potentially utilizing the feeds in Oregon, to derive an estimate of the total amount of DF that could be used.

The total weight of DF potentially used was correlated with the joint-product ethanol equivalent. From this estimate, the size of ethanol plant(s) needed to produce the quantity of DF potentially consumed, was calculated.

As an example in Table 24, distillers' dried grain (DDG) from corn is being used in a ration designed to put 1.5 to 2 pounds of gain on feeder cattle over a six-month period. As noted earlier, DF must compete economically with soybean meal, grass hay, corn, barley, and corn silage in the ration and meet the nutritional constraints in the model. The program requires that 15.5 pounds of dry matter be fed daily.

In the ration only a small percent (2.38 percent) of the total dry weight was made up of DDG when priced at $165 per ton. However, when the price is lowered to between $55 and $90 per ton, large amounts of DDG (more than 30 percent of the ration) will be utilized. When the price drops below $55 a ton, no more enters the ration (this is the same relationship illustrated in Figure 5).

The sensitive price range for each feed in each ration is the most pertinent. It is here that a small percentage decrease in price will bring about a larger percentage increase in the quantity used. The demand at this point

Table 24. Potential DDG Corn Use and Alcohol Equivalent in Oregon

Dairy Ration (44 pounds dry weight fed per day, 365 days)

Price	$/ton	Pounds fed per day	Cows in Ore. (1979)	Pounds DDG Utilized		Ethanol Equivalent[a]	
		(as fed basis)		(per day)	(per year)	(gal/day)	(gal/yr)
High	190	2.92	93,000	271,560	99.12 M	64,657	23.60 M
Sensitive	137-190	4.74	93,000	440,820	160.90 M	104,957	38.31 M
Low	136	6.44	93,000	598,920	218.61 M	142,600	52.05 M

Beef Finishing Ration (22 pounds dry weight fed per day, 18 days)

Price	$/ton	Pounds fed per day b/	Cattle on feed (1979)	Pounds DDG Utilized		Ethanol Equivalent	
		(as fed basis)		(per day)	(per year)	(gal/day)	(gal/yr)
High	180	1.03	147,000	151,410	2.73 M	36,050	.65 M
Sensitive	110-170	2.54	147,000	373,380	6.72 M	88,900	1.60 M
Low	100	16.51	147,000	2,426,970	43.69 M	577,850	10.40 M

Beef Feeder Ration (15.5 pounds dry weight per day, 6 months)

Price	$/ton	Pounds fed per day b/	Cattle on feed (1979)	Pounds DDG Utilized		Ethanol Equivalent	
		(as fed basis)		(per day)	(per year)	(gal/day)	(gal/yr)
High	165	2.38	147,000	349,860	63.85 M	83,300	15.20 M
Sensitive	55-90	5.50	147,000	808,500	147.55 M	192,500	35.13 M
Low	55	10.03	147,000	1,474,410	269.08 M	351,050	64.07 M

a/ One gallon ethanol per 4.2 pounds of DDG.

b/ The AGNET program substitutes DDG for more than 50% of the total dry matter intake but current studies indicate that 30% may be the maximum substitution level [Kienholz 1979; Ward, 1980].

Table 25. Potential Wheat DDGS Use and Alcohol Equivalent in Oregon

Dairy Ration (44 pounds dry weight fed per day, 365 days)

Price	$/ton	Pounds fed per day (as fed basis)	Cows in Ore.(1979)	Pounds DDGS Utilized (per day)	Pounds DDGS Utilized (per year)	Ethanol Equivalent[a] (gal/day)	Ethanol Equivalent[a] (gal/yr)
High	196	9.41	93,000	875,130	319.42 M	125,019	45.63 M
Sensitive	75-190	10.10	93,000	939,300	342.84 M	134,186	48.98 M
Low	37	29.20	93,000	2,715,600	991.19 M	387,943	141.60 M

Beef Finishing Ration (22 pounds dry weight fed per day, 18 days)

Price	$/ton	Pounds fed per day (as fed basis)	Cattle on feed (1979)	Pounds DDGS Utilized (per day)	Pounds DDGS Utilized (per year)	Ethanol Equivalent (gal/day)	Ethanol Equivalent (gal/yr)
High	187	2.09	147,000	307,230	5.53	43,890	.79 M
Sensitive	95-100[b]	9.10	147,000	1,337,700	24.08 M	191,100	3.44 M
Low	95	12.24	147,000	1,799,280	32.39 M	257,040	4.63 M

Beef Feeding Ration (15.5 pounds dry weight per day, 6 months)

Price	$/ton	Pounds fed per day (as fed basis)	Cattle on feed (1979	Pounds DDGS Utilized (per day)	Pounds DDGS Utilized (per year)	Ethanol Equivalent (gal/day)	Ethanol Equivalent (gal/yr)
High	195	.80	147,000	117,600	21.46 M	16,800	3.07 M
Sensitive	55-70	10.00	147,000	1,470,000	268.27 M	210,000	38.32 M
Low	55	11.18	147,000	1,643,460	299.93 M	234,780	42.85 M

a/ One gallon ethanol per 7 pounds DDGS.

b/ The AGNET program substitutes DDGS for more than 40% of the total dry matter intake, but current studies indicate that 30% may be the maximum substitution level [Kleinholz, 1979; Ward, 1980].

c/ The AGNET program substitutes DDGS for more than 60% of the total dry matter intake, but current studies indicate that 30% may be the maximum substitution level [Kleinholz, 1979; Ward, 1980].

Table 26. Potential Wheat Stillage Use and Alcohol Equivalent in Oregon

Dairy Ration (44 pounds dry weight fed per day, 365 days)

Price	$/ton	Pounds fed per day a/	Cows in Ore. (1979)	Pounds Stillage Utilized		Ethanol Equivalent b/	
		(as fed basis)		(per day)	(per year)	(gal/day)	(gal/yr)
High	28	8.83	93,000	821,190	299.73 M	117,313	42.82 M
Sensitive	14-27	18.00	93,000	1,679,000	611.01 M	239,143	87.29 M
Low	14	25.56	93,000	2,377,080	867.63 M	339,503	123.95 M

Beef Finishing Ration (22 pounds dry weight fed per day, 18 days)

Price	$/ton	Pounds fed per day	Cattle on feed (1979)	Pounds Stillage Utilized		Ethanol Equivalent	
		(as fed basis)		(per day)	(per year)	(gal/day)	(gal/yr)
High	6	5.39 c/	147,000	792,330	14.26 M	113,190	2.04 M
Sensitive	5-6	5.50 c/	147,000	808,500	14.55 M	115,500	2.08 M
Low	5	21.88	147,000	3,216,360	57.89 M	459,480	8.27 M

Beef Feeding Ration (15.5 pounds dry weight per day, 6 months)

Price	$/ton	Pounds fed per day	Cattle on feed (1979	Pounds Stillage Utilized		Ethanol Equivalent	
		(as fed basis)		(per day)	(per year)	(gal/day)	(gal/yr)
High	15	8.44	147,000	1,240,680	226.42 M	177,240	32.35 M
Sensitive	5-15	10.00	147,000	1,470,000	268.27 M	210,000	38.32 M
Low	5	21.22	147,000	3,119,340	569.28 M	445,620	81.33 M

a/ Using wet wheat stillage, feeding capacity may be limited because the stillages usually contain high percentages (90-79%) of water.

b/ Using wet stillage feeding capacity may be limited because it contains 3-10% dry matter as feed.

c/ The AGNET program substitutes wheat stillage for more than 40% of the total dry matter intake, but current studies indicate the 30% may be the maximum substitution level [Kienholz, 1979; Ward, 1980].

Table 27. Potential Distillers' Dried Potato Use and Alcohol Equivalent in Oregon

Dairy Ration (44 pounds dry weight fed per day, 365 days)

Price	$/ton	Pounds fed per day a/	Cows in Ore. (1979)	Pounds of DDP Utilized		Ethanol Equivalent b/	
		(as fed basis)		(per day)	(per year)	(gal/day)	(gal/yr)
High	117	3.27	93,000	304,110	111.00 M	28,963	10.57 M
Sensitive	55-117	5.75	93,000	534,750	195.18 M	50,929	18.59 M
Low	40	6.05	93,000	646,350	235.92 M	61,557	22.47 M

Beef Finishing Ration (22 pounds dry weight fed per day, 18 days)

Price	$/ton	Pounds fed per day	Cattle on feed (1979)	Pounds DDP Utilized		Ethanol Equivalent	
		(as fed basis)		(per day)	(per year)	(gal/day)	(gal/yr)
High	155	3.47	147,000	510,090	9.18 M	48,580	.87 M
Sensitive	95-100	8.50 c/	147,000	1,249,500	22.49 M	119,000	2.14 M
Low	95	14.38	147,000	2,113,860	38.05 M	201,320	3.62 M

Beef Feeding Ration (15.5 pounds dry weight per day, 6 months)

Price	$/ton	Pounds fed per day	Cattle on feed (1979)	Pounds DDP Utilized		Ethanol Equivalent	
		(as fed basis)		(per day)	(per year)	(gal/day)	(gal/yr)
High	145	1.44	147,000	211,680	38.63 M	20,160	3.68 M
Sensitive	60-90	13.50 d/	147,000	514,500	93.90 M	49,000	8.94 M
Low	55	12.14	147,000	1,784,580	325.69 M	169,960	31.01 M

a/ Using wet potato stillage, feeding capacity may be limited because the stillages usually contain high percentages of water.

b/ Assumes 10.5 pounds of Distillers; Dried Potatoes per gallon of ETOH produced.

c/ The AGNET program substitutes DDP for more than 58% of the total dry matter intake, but current studies indicate that 30% may be the maximum substitution level [Kienholz, 1979; Ward, 1980].

d/ The AGNET program substitutes DDP for more than 65% of the total dry matter intake, but current studies indicate that 30% may be the maximum substitution level [Kienholz, 1979; Ward, 1980].

appears relatively elastic. In theory, if the demand for a commodity is elastic, total revenue can be increased by decreasing price. This happens because each incremental price drop results in a relatively larger increase in sales.

Continuing with Table 24, in the beef finishing ration, 22 pounds of dry weight are fed per head per day. In the sensitive price range, up to 6 pounds of DDG corn would be fed per day for 18 days (see Table 24). It should be noted that while 6 pounds is the maximum amount fed in the sensitive range, Table 24 shows 2.54 pounds, which is the mid-point of this range. In 1979, there were approximately 147,000 cattle on feed in Oregon. These cattle could have utilized approximately 15.88 million pounds of DDG corn. That quantity could have been produced by ethanol plants producing approximately 3.78 million gallons of ethanol from corn. The rest of Table 24 and Tables 25, 26, and 27 are interpreted in a similar fashion.

There are no unilateral generalizations to be drawn from the tables; it is important to study each table carefully. Generally, DF seem to have a higher value in the sensitive price range for dairy feed than they do in either of the beef feeding or finishing rations. However, this does not hold true for distillers' dried potatoes where the value is higher in the beef finishing ration than the other two. The implication is that different DF have different feeding characteristics. Depending upon the price of other feeds in the ration, different quantities enter in at different prices. The feed program specifies certain nutrient qualities in each of the feeds. These vary between feedstocks and within feedstock categories. For example, alfalfa may range from 12 to 22 percent crude protein as well as having different feeding qualities than corn. A change in either the nutritional content of the feeds, or a change in feed prices, will change the resulting DF use pattern.

Dairy cattle are on feed 365 days a year, beef feeder cattle are fed six months, and beef finishing cattle approximately 2 to 3 weeks. This affects the total annual amount of DF utilized. The dairy sector ranks first, the beef feeder sector second, and the beef finishing sector third for DDGS wheat and wheat stillage use. For DDG corn and DD potatoes, the beef sector ranks first, the dairy sector second, and the beef finishing sector third.

The amount of DF produced per gallon of ethanol produced varies depending on the feedstock. There is one gallon of ethanol produced for every 4.2 pounds of DDG corn. But for DDGS wheat and wheat stillage, 7 pounds of distillers' dried grains and solubles are assumed per gallon of ethanol production. When potatoes are the feedstock, 10.5 pounds of DDP are produced in conjunction with one gallon of ethanol. More than twice as much DDP are produced per gallon of ethanol (10.5 pounds per gallon) than DDG corn (4.5 pounds per gallon).

In some cases the quantity of ethanol that would be produced in conjunction with the DF looks impressive. For example, in the sensitive range of the feeder ration alone, the distillers' dried grain from corn would have an ethanol equivalent of 35.13 million gallons per year, the feeder ration for DDGS wheat would have an ethanol equivalent of 38.32 million gallons per year, etc. Cattle on feed could utilize each ration, but only one at a time. Therefore, each distillers' feeds would be competing to feed the same cattle. Thus, the ethanol equivalents are <u>not</u> additive from one table to the next in Tables 24 through 27.

The ethanol equivalents or the total pounds of DF utilized are additive within a table. For example, in Table 24 DDG corn and its ethanol equivalent do not compete for the same livestock at the same time so 161 million pounds would be fed to the dairy sector, plus 154 million pounds to beef cattle split between feeders and finishers. This indicates that 315 million pounds of DDG corn could be fed in Oregon, for prices in the sensitive price range. The ethanol equivalent of this quantity would be approximately 75 million gallons annually. This study analyzes only dairy and beef cattle. As data are developed, the same kind of analysis could be carried out for other livestock in Oregon.

While these data have been developed for Oregon, it would be short-sighted to ignore the economic influence of other Pacific Northwest states. Oregon ethanol might be sold to other states because of state tax subsidies. Like ethanol, both livestock and feeds are transportable across state lines and specific geographic locations may be more important than state boundries. Examples are the Columbia Basin on both sides of the Columbia River and the fertile valley on the western side of the Cascades in both Oregon and Washington. There are some similar implications, although smaller in total size, between Oregon and Idaho in the Snake River Valley and between Oregon and California in the Klamath Basin.

Aggregate Demand for Dried Distillers' Feeds in Oregon

The aggregate beef and dairy demand for each distiller's feed--DDG corn, DDGS wheat, and DDS potatoes--is derived in Tables 28, 29, and 30. No aggregate demand was derived for wheat stillage as it is a substitute product for DDGS wheat in the alcohol conversion process.

By first converting pounds fed per day to pounds fed per year (by livestock class), the demand for the three livestock sectors was summed to estimate the aggregate demand for the specified distillers' feeds, as indicated in the right hand column in Tables 28, 29, and 30.

Using corn as an example in Table 28, dairy cattle will demand DDG corn at the highest price, then finishers, and then feeders. As the price of DDG corn drops, all three sectors will demand more until their diet constraint is reached.

As with the previous estimates of the demand schedule for each distillers' feed (Figures 6 through 8), the prices of substitute feeds are held at a constant level in this analysis.

The additional pounds of DF demanded because of a price decrease for each livestock sector are plotted in Figures 9, 10, and 11. As expected, these figures show that as the price of DF decreases, the feed demand from dairy, feeder, and finishing cattle enterprises in Oregon increases.

When interpreting these results, it is important to recognize that the same cattle inventory is used to estimate consumption of each of the distillers' feeds. As a result, the schedules for the respective distillers' feeds are not additive. All the dairy, feeder, and finishing cattle in Oregon could consume 532.8 million pounds of DDG corn, or 1,324 million pounds of DDGS wheat, or 600 million pounds of DD potatoes. The next section of this report will analyze the cumulative dairy and beef feed demand for the combined supply of distillers' feeds.

Table 28. Aggregate Demand for DDG Corn

Price of DDG Corn	Enterprise	Lbs. Fed per Animal per Day	No. of Animals	No. of Days Fed	Lbs. Fed to Oregon Cattle per Year	Total Pounds of DDG Corn Fed to Oregon Cattle per Year
($/ton)					-million-	-million-
190.16	Dairy	2.92	93,000	365.0	99.12	99.12
180.00	Finishing	1.03	147,000	18.0	2.73	101.85
178.00	Finishing	2.68	147,000	18.0	7.09	106.21
167.80	Dairy	4.74	93,000	365.0	160.90	167.99
165.00	Feeder	2.38	147,000	182.5	63.85	231.84
155.39	Dairy	6.35	93,000	365.0	215.55	286.49
136.96	Dairy	6.44	93,000	365.0	218.61	289.55
111.00	Finishing	5.88	147,000	365.0	15.56	298.02
110.00	Finishing	16.51	147,000	365.0	43.69	326.15
91.00	Feeder	2.71	147,000	18.0	72.70	335.00
90.00	Feeder	2.97	147,000	182.5	79.68	341.98
71.00	Feeder	6.80	147,000	182.5	182.43	444.73
66.00	Feeder	7.73	147,000	182.5	207.38	469.68
65.00	Feeder	9.83	147,000	182.5	269.71	526.01
55.00	Feeder	10.03	147,000	182.5	269.08	531.38

Table 29. Aggregate Demand for DDGS Wheat

Price of DDGS Wheat	Enterprise	Lbs. Fed per Animal per Day	No. of Animals	No. of Days Fed	Lbs. Fed to Oregon Cattle per Year	Total Pounds of DDGS Wheat Fed to Oregon Cattle per Year
($/ton)					-million-	-million-
195.40	Dairy	9.41	93,000	365.0	319.42	319.42
193.00	Feeder	.80	147,000	182.5	21.46	340.88
191.00	Feeder	1.91	147,000	182.5	51.24	370.66
188.00	Finishing	2.09	147,000	18.0	5.53	376.19
146.00	Dairy	10.03	93,000	365.0	340.47	397.24
104.20	Dairy	13.78	93,000	365.0	467.76	524.53
103.00	Dairy	28.41	93,000	365.0	964.38	1021.15
103.00	Feeder	2.09	147,000	182.5	65.07	1025.98
98.00	Finishing	12.24	147,000	18.0	32.39	1052.84
97.00	Feeder	2.21	147,000	182.5	59.29	1056.06
72.60	Dairy	29.01	93,000	365.0	984.74	1076.42
67.00	Feeder	8.04	147,000	182.5	215.69	1232.82
64.00	Feeder	11.01	147,000	182.5	295.37	1312.50
56.00	Feeder	11.18	147,000	182.5	299.93	1317.06
36.80	Diary	29.20	93,000	365.0	991.19	1323.51

Table 30. Aggregate Demand for DD Potatoes

Price of DD potatoes	Enterprise	Lbs. fed per animal per day	No. of animals	No. of days fed	Lbs. fed to Oregon cattle per year	Total pounds of DD potatoes fed to Oregon cattle per year
($/ton)					-million-	-million-
153.84	Finishing	3.47	147,000	18.0	9.18	9.18
144.51	Feeder	1.44	147,000	182.5	38.63	47.81
142.29	Feeder	3.10	147,000	182.5	83.17	92.35
117.40	Dairy	3.27	93,000	365.0	111.00	203.35
97.40	Diary	5.30	93,000	365.0	179.91	272.26
97.14	Finishing	14.38	147,000	18.0	38.05	301.13
86.20	Dairy	6.74	93,000	365.0	228.79	350.01
85.05	Feeder	3.50	147,000	182.5	93.90	360.74
68.31	Feeder	10.79	147,000	182.5	289.47	556.31
63.06	Feeder	12.10	147,000	182.5	324.61	591.45
58.66	Feeder	12.14	147,000	182.5	325.69	592.53
40.00	Dairy	6.94	93,000	365.0	235.92	599.66

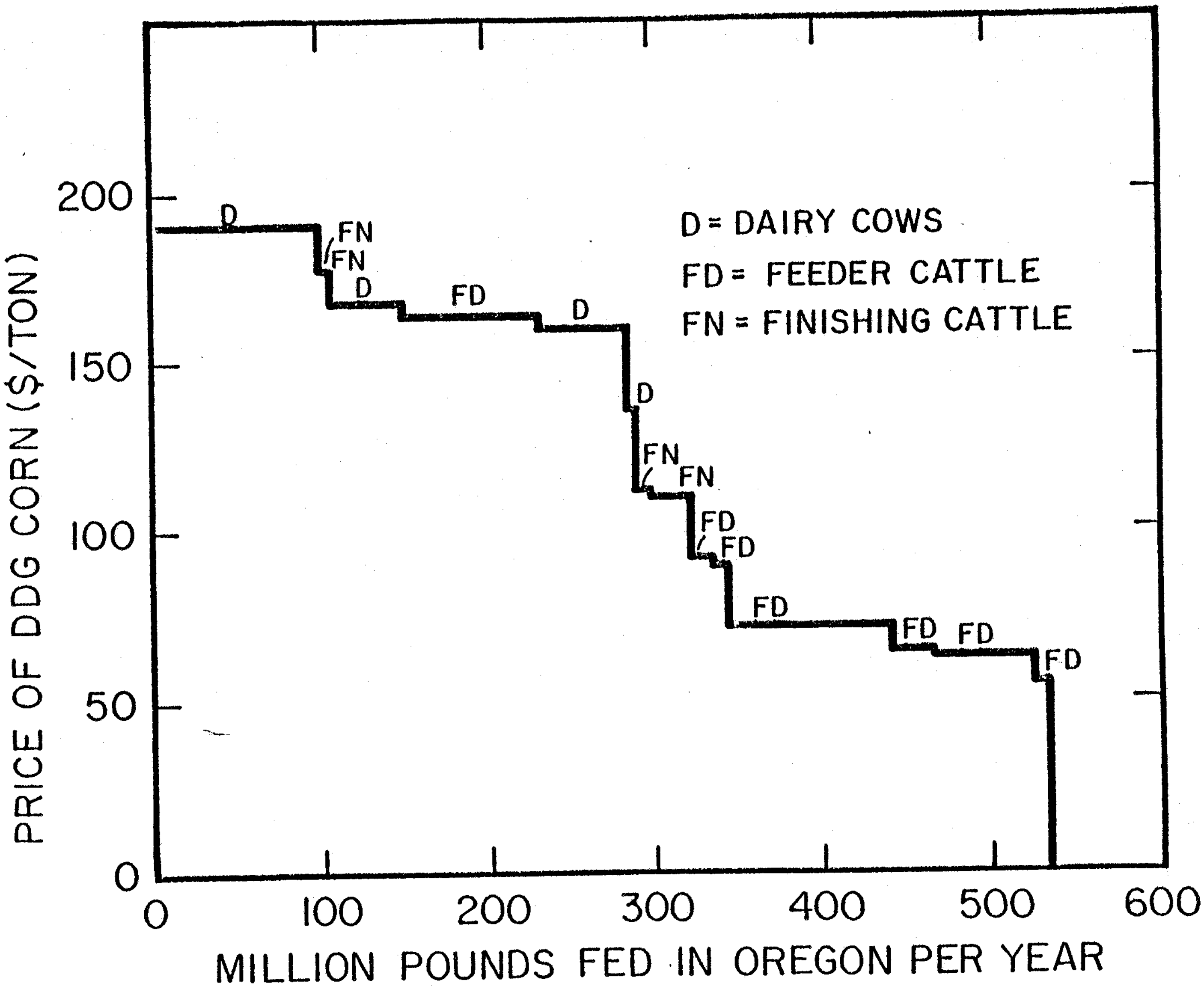

FIG. 9 AGGREGATE DEMAND FOR DDG CORN

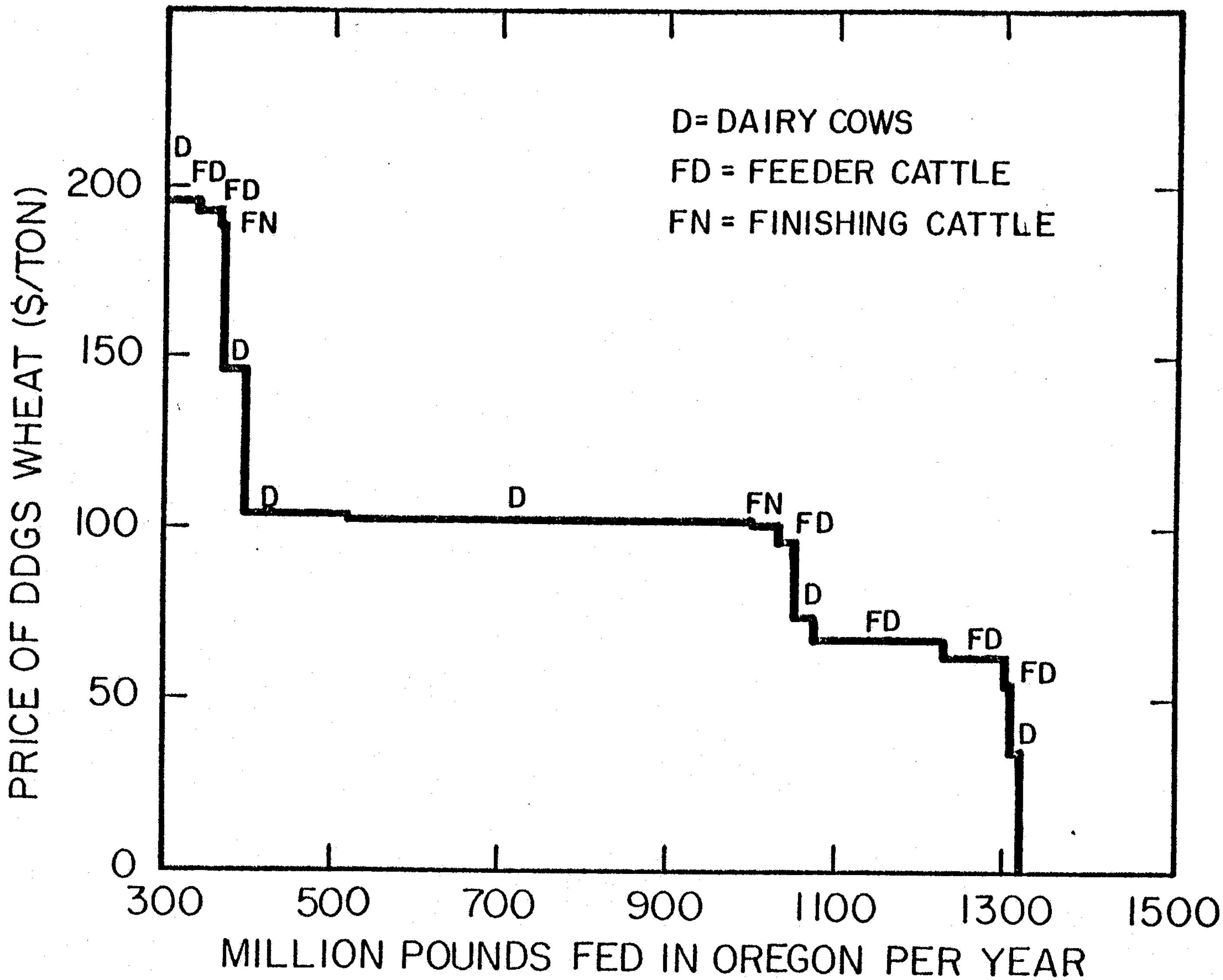

FIG. 10 AGGREGATE DEMAND FOR DDGS WHEAT

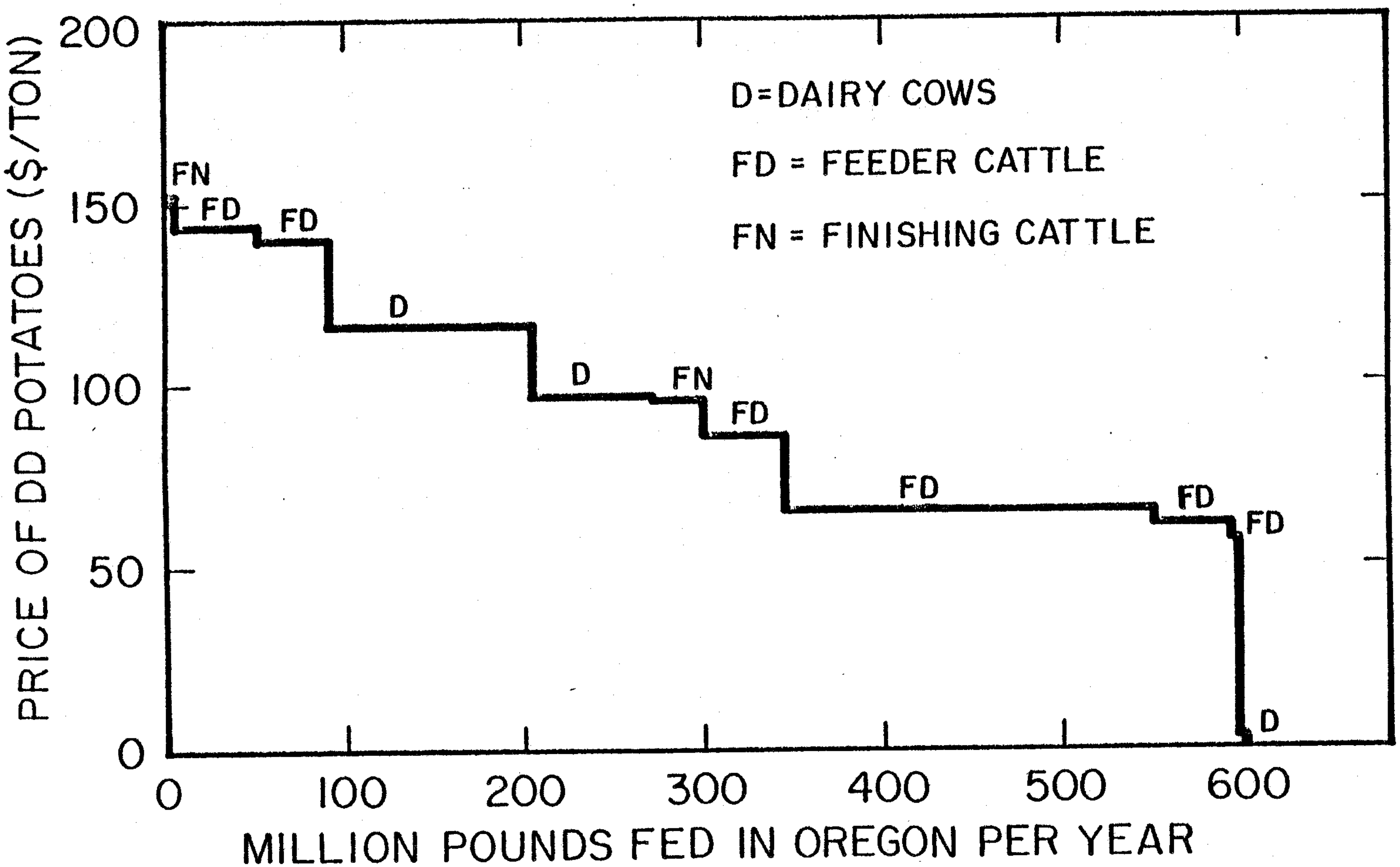

FIG. 11 AGGREGATE DEMAND FOR DD POTATOES.

VII. THE ECONOMIC POTENTIAL FOR ETHANOL PRODUCTION

Break-Even Costs of Production

The final step in assessing overall economic feasibility for ethanol production involves combining the previous findings concerning cost of production, feedstock availability, and the demand for ethanol and distillers' feeds. A linear programming computer model was developed to estimate break-even costs per gallon of ethanol, given the constraints imposed by the above economic parameters.

Assumptions

Three feedstock alternatives were considered: cull potatoes, barley, and wheat. Barley was selected over corn as being more representative of Oregon agricultural production.

The quantities of the feedstocks available were assumed to be limited by the amounts produced in the state. The quantity of cull potatoes assumed to be available was approximately 10 percent of the five-year average commercial potato production for the state; a total of 2.65 million hundredweight. It is assumed that 8.81 million bushels of barley and 55.04 million bushels of wheat would be available. Again these totals were based on the state's average production for the last five years.

It was assumed that the distillers' feeds produced from these feedstocks could be fed as part of a beef finishing program, in feeder cattle rations, or to dairy cows. The demand for the distillers' feeds was assumed to be limited by the numbers of these livestock in the state. Livestock feeding was constrained by the number of head days available. This amounted to 2.646 million head days for finishing rations, 26.828 million head days for feeder cattle rations, and 33.945 million head days for dairy cows. The amounts of the various distillers' feeds fed per head per day and the values of these feeds in the ration when fed at these levels, were estimated using the least cost feed model described earlier (Tables 28, 29, and 30).

Because of the interest in neighboring states for developing their own ethanol industries, ethanol production in Oregon was constrained by the feedstocks available and the markets available for the distillers' feed within the state. It can be expected that distillers' feeds produced in Oregon will be shipped to Washington markets and feedstocks produced in Washington will be available for ethanol production in Oregon but reverse flows are also likely and constraining the model at the statewide levels provides a reasonable basis for projecting the potential for ethanol production in Oregon.

Important assumptions in this analysis of ethanol production potential are the price levels for the feedstocks and the alternative feeds available for use in livestock rations. The following prices are assumed:

<u>Ethanol Feedstocks</u>	
Cull potatoes ($/cwt)	$ 1.00
Barley ($/bu)[11/]	2.95
Wheat ($/bu)	4.26
<u>Livestock Feed Prices</u>	
Alfalfa hay ($/ton)	$120
Grass Hay ($/ton)	60
Corn silage ($/ton)	25
Soybean meal ($/ton)	250
Barley ($/bu)[11/]	3.12
Corn ($/bu)	3.33

[11/] The difference in barley price is because of the transaction cost, i.e., the difference between the buying and selling price.

For this analysis it was assumed that ethanol would be produced using the technology and costs represented by the mid-size community/co-op plant. This facility has an output capacity of one million gallons of ethanol annually, at a cost of 90 cents per gallon of ethanol produced excluding the feedstock cost (to Table 15).

The following conversion rates were assumed for ethanol and distillers' feed production:

Feedstock	Ethanol (gal/unit)	Distillers' Feed (lbs/unit)
Cull Potatoes (cwt)	1.12	3.87
Barley (bu)	1.52	19.30
Wheat (bu)	2.08	20.70

Results

To estimate the potential for ethanol production, the linear programming model was solved at various assumed price levels for ethanol. The price of ethanol was varied from $1.50 per gallon to $2.60 per gallon. The findings in Table 31 represent three alternative scenarios. About three million gallons of ethanol, representing less than one-quarter of 1 percent of the total gasoline used in Oregon, could be produced at a break-even cost of $1.55 for ethanol. At $1.80 per gallon, 15 million gallons could be produced. And at a break-even ethanol cost of $2.23, production could reach more than 40 million gallons, or about three percent of the state's total gasoline consumption.

The findings illustrate the importance of feedstock cost and distillers' feed credit in the overall feasibility of ethanol production. As a relatively cheaper feedstock, cull potatoes are the most economical; however, a single 3-million gallon ethanol plant could handle all the cull potatoes produced in Oregon.

The larger 15- and 43-million gallon output levels as formulated in this model would be forced to draw upon the relatively higher cost barley and wheat for feedstock. Despite a higher value of the distillers' feed, the initial feedstock costs for barley and wheat would push ethanol break-even costs higher at successively larger output.

At the moderate production level, 15 million gallons of ethanol would be produced, using cull potatoes and barley in this model. Almost all the barley produced in Oregon would be required in addition to all the cull potatoes.

At the high production level, cull potatoes, barley, and wheat would be required. To implement this alternative would require that 28 percent of Oregon's average annual wheat crop would be converted to ethanol. One reason a higher break-even price for ethanol is required for the high production alternative is that to utilize (in livestock rations) the production of distillers' feeds, ethanol must be priced at a lower level. Notice that the value of distillers' feeds varies with production output in Table 31, especially at the 43-million gallon level. This is because supply--in terms of distillers' feed--is increased, but livestock feed demand is unchanged. As a result, DF price declines as successively larger amounts are marketed.

In summary, the economic feasibility analysis indicates that a return of at least $1.50 per gallon of ethanol is necessary to economically produce ethanol, given feedstock prices and distillers' feed values. At the high level of ethanol production (43 million gallons annually), approximately three percent of the annual gasoline consumption for Oregon could be achieved, but at a break-even cost considerably above current prices of unleaded gasoline. Furthermore, at this level of production, feedstock requirements would exhaust all the cull potatoes, most of the barley, and more than one-fourth of the wheat produced in Oregon.

Table 31. Potential Ethanol Production in Oregon and Break-even Costs per Gallon at Three Levels of Output

	Ethanol Production Level		
	Low	Moderate	High
Ethanol production (mil.gal.)	3	15	43
Feedstocks used:			
Cull potatoes (mil. cwt)	2.65	2.65	2.65
Barley (mil.bu.)	0	7.93	5.16
Wheat (mil.bu.)	0	0	15.43
Value of distillers' feeds from			
Cull potatoes ($/ton)	144	144	88
Barley ($/ton)	--	164	93
Wheat ($/ton)	--	--	140
Break-even cost of producing ethanol ($/gal.)	$ 1.55	$ 1.80	$ 2.23

It must be recognized that the assumptions made to assess feasibility in the above example are restrictive regarding feedstock selection, still size, and product prices. These results, therefore, cannot be routinely generalized for all other possible situations.

There is some economic potential for ethanol production in Oregon, particularly in anticipation of higher liquid fuel prices. The short-run prospects appear most promising for utilizing agricultural by-products such as cull potatoes. To achieve successively higher levels of ethanol, output will require greater dependence on commercial crops or the development of alternative energy-specific crops. The higher valued commercial crops significantly increase feedstock costs and resulting break-even costs of ethanol.

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APPENDICES

APPENDIX I

COMMERCIAL CROPS IN OREGON - 1975-1979 PRODUCTION AND PRICES

A. Barley

Barley acreage in Oregon has decreased from more than 400,000 acres in the early 1960s to less than 160,000 acres in 1979. With average barley yields of 45 to 50 bushels per acre, Oregon's annual barley production is about 8 million bushels, down from 17 million bushels in the early 1960s. It is the state's second largest grain crop, yielding an annual production value of approximately 20 million dollars. Widely dispersed across the state, it is grown in 30 of 36 counties. Some barley goes for malting and some for livestock feed, but 60 to 70 percent is exported.

Table I-1. Oregon Barley Production and Prices, 1975-1979

Year	1975	1976	1977	1978	1979	Average
Quantity (1000 tons)	208.20	176.60	214.30	222.00	192.00	202.62
Price ($/ton)	105.43	98.34	78.75	79.17	102.08	92.75
($/bushel)	2.53	2.36	1.89	1.91	2.45	2.23

B. Wheat

Wheat is Oregon's principal grain crop with annual production of 50 to 60 million bushels a year on approximately 1.3 million acres. The average state yield is between 40 and 45 bushels per acre with an annual value of 200 to 250 million dollars. Wheat is grown in 30 of the 36 Oregon counties throughout the state except along the coast. Winter wheat accounts for 92.5 percent of the state's wheat, with spring wheat comprising the remainder. The Columbia

Basin in north central Oregon accounts for 50 to 60 percent of the state's total production and the Willamette Valley for approximately 25 percent. Wheat is one of the crops grown on the increasing acreage being developed under irrigation in the Columbia Basin. Eighty to 90 percent of Oregon's wheat is exported, mostly through the Port of Portland.

Table I-2. Oregon Wheat Production and Prices, 1975-1979

Year	1975	1976	1977	1978	1979	Average
Quantity (1,000 bu.)	58,040	60,304	47,620	51,925	57,300	55,037.2
Price ($/bu.)	3.78	2.79	2.77	3.51	3.85	3.34

C. Corn

Oregon ranks third in the nation and produces about 13 percent of the sweet corn processed in the United States with a crop value of approximately $20 million. Yields approach 8.5 tons per acre.

Sweet corn is grown on approximately 40,000 acres, mostly in the Willamette Valley. Some sweet corn is grown in the Columbia Basin-Milton-Freewater area, and in the Snake River area around Ontario. The Willamette Valley is well suited for sweet corn production because weather conditions allow the corn to remain in prime quality for a number of days, insuring an orderly harvest. A high percentage of the processed sweet corn is frozen and marketed nationally.

Table I-3. Oregon Sweet Corn for Processing, Production, and Prices, 1975-1979

Year	1975	1976	1977	1978	1979	Average
Quantity (1,000 tons)	319.20	312.75	301.70	320.00	322.43	315.22
Price ($/ton)	61.70	57.30	64.40	58.60	59.60	60.32

D. Corn for Grain

There are approximately 11,000 acres of corn planted for grain in Oregon with an annual sales value approaching $2 million. More than 60 percent of the total production is in the Snake River district of Malheur County. Twenty-five percent is in the Columbia Basin and the remainder in Marion, Polk, Yamhill, and Douglas Counties.

The average corn for grain yield is approximately 100 bushels/acre. It is considerably higher (130 bushels/acre) in the Columbia Basin.

Table I-4. Oregon Corn for Grain, Production, and Prices, 1975-1979

Year	1975	1976	1977	1978	1979	Average
Quantity (1,000 tons)	19.0	25.2	31.9	34.6	30.8	28.3
Price ($/bu.)	3.05	2.75	2.45	2.65	3.00	2.78

E. Corn Silage

Approximately half the corn grown for silage is in the Willamette Valley district; another 40 percent is split evenly between the Columbia Basin and the Snake River Basin. The remainder is grown in other districts.

Over the last five years about 32,000 acres of corn silage have been harvested with an average yield of 20 to 22 tons. The 1979 value of this crop approaches $4 million. Most corn silage is used as a livestock feed where it is grown.

Table I-5. Oregon Corn Silage, Production, and Prices, 1975-1979

Year	1975	1976	1977	1978	1979	Average
Quantity (1,000 tons)	672	735	620	600	704	666.20
Price ($/ton)	17.00	18.21	16.10	14.80	18.50	16.92

F. Potatoes

Oregon's potato acreage produces some of the highest yields in the nation averaging approximately 400 hundredweight per acre. Some 60,000 to 70,000 acres of irrigated potatoes produce 25 million hundredweight. The annual farm sale value is approximately $70 million. Potatoes are the state's ranking crop in terms of farm sales.

Potatoes are produced throughout the state. In Hermiston-Boardman, thousands of acres of the newly irrigated lands have come into production with potatoes one of the primary cash crops. The Columbia Basin district produces 60 percent of Oregon's potato crop.

Most potatoes are planted in the spring with russets the major variety. The processing market is taking an increasing share of total production. Yet the fresh market remains an important part of the potato industry, particularly in the Klamath Falls area. Oregon also produces about 3,000 acres of seed potatoes.

Table I-6. Oregon Potatoes, Production, and Prices, 1975-1979

Year	1975	1976	1977	1978	1979	Average
Quantity (1,000 bu.)	58,040	60,301	47,620	51,925	57,300p	55,037.2
Price ($/cwt)	3.19	2.71	2.89	2.76	2.71	2.85

G. Sugar Beets

Historically, sugar beets have been grown in the Willamette Valley with some production in the Columbia Basin. The quantity of sugar beets in the last five years has declined by more than 50 percent from more than 400,000 tons per year to less than 200,000 tons.

Table I-7. Oregon Sugar Beets, Production, and Prices, 1975-1979

Year	1975	1976	1977	1978	1979	Average
Quantity (1,000 tons)	426	364	206	203	178	275.4
Price ($/ton)	22	19	23	26	25.60	23.12

APPENDIX II

BIOMASS-ALCOHOL CONVERSION FACTORS FOR SELECTED RESIDUES AND WASTES

Wood and Ag Residues:	173 gal. methanol/dry ton
	47 gal. ethanol/dry ton
Sugars:	136 gal. ethanol per ton of fermentable sugars
Metropolitan Solid Wastes:	100 gal. methanol/dry ton
	25 gal. ethanol/dry ton
Citrus Waste:	107 gal. ethanol/dry ton
Cheese Waste:	95 gal. ethanol/dry ton
Other Food Processing Wastes:	90 gal. ethanol/dry ton

SOURCE: United States Department of Energy. The Report of the Alcohol Fuels Policy Review, June 1979, p. 56.

APPENDIX III

ALCOHOL CONVERSION FACTORS FOR
SELECTED AGRICULTURAL COMMODITIES

	Probable Commercial Yield of 199 Proof Ethanol			
	Per Bushel Fermentable Content		Per Ton Fermentable Content	
	Average	High	Average	High
	gallons			
Corn	2.35	2.62	84.0	93.6
Grain Sorghum	2.22	2.70	79.5	96.4
Wheat	2.57	2.74	85.0	91.4
Rye	2.20	2.54	78.8	91.0
Oats	1.02	1.05	63.6	66.8
Barley	1.90	2.05	79.2	85.5
Rice	1.79	2.21	79.5	98.2
Potatoes	0.69	0.79	22.9	26.3
Sweet Potatoes	0.94	1.29	34.2	46.6
Yams	0.75	1.00	27.3	36.6
Jerusalem Artichokes	0.60	0.75	20.0	25.0
Sugar Beets	-	-	22.1	24.9
Sugar Cane	-	-	15.2	17.3
Sweet Sorghum	NA	NA	NA	NA
Apples	0.35	0.38	14.4	15.7
Peaches	0.28	0.37	11.5	15.3

NA - Not Available.

SOURCE: United States Department of Agriculture, Motor Fuels from Farm Products, Miscellaneous Publication No. 327, Washington, D.C., December 1938.

APPENDIX IV

COMPONENT COSTS FOR A FARM STILL

Unit/Component	Cost
Grain Storage (4,000 bu. @ $1.26/bu.)	$ 5,040
Hammer Mill	500
Grain Conveyer	1,600
Cook Tanks with Coils (400 gal. x 3 tanks @ $902 ea.)	2,706
Mixer for Cook Tanks	2,400
Motor for Mixer	420
Solids Separator	800
Fermentation Tank (400 gal.)	1,470
Reboiler and Preheater	720
Distillation Columns a/	3,500
Condenser	150
Accumulator	220
Denaturant Unit	470
Alcohol Storage Tank	400
By-product Storage Tank (wet slops)	120
Plumbing	230
Pumps	1,230
Valves (motor actuated)	1,015
Valves (float)	50
Valves (other)	50
Flow Meters	500
Thermocouples	529
Thermocouple Switch and Panel	275
Heat Controller for Reflux Loop	280
Digital Readout Meter	400
Wagon Box Dryer	5,000
Computer	500
Gasifier	8,000
Paint and Insulation	25
Heat/Cooling Recovery Systems	1,500
Labor	3,400
Miscellaneous (freight, etc.)	500
ESTIMATED TOTAL COSTS FOR SYSTEM	$44,000 b/

a/ Includes well casing, perforated plates, spacers, downcomers and cups, domes and bottoms, fittings, etc.

b/ Buildings to house the still are not included.