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ETHANOL FROM GRAIN: ECONOMIC BALANCES OF SMALL SCALE PRODUCTION (0.25 - 2.5 million gal./yr.)

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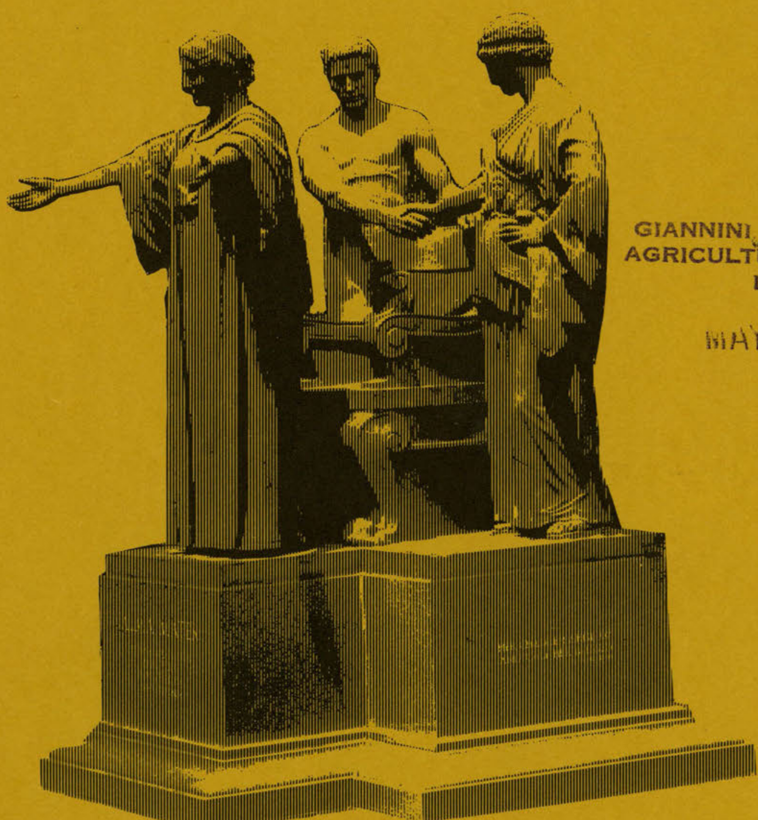

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Energy Used For Processed Livestock Feed

by

Folke Dovring

Purchased feed is a considerable item of expenditure for American livestock farmers. In recent years it has amounted to about one-sixth of all expenses for farm production in the United States, or one-fourth or more of all operating expenses. Needless to say, it amounts to much larger fractions of expenses on the farms where it is used. In 1977, feeds purchased by U.S. farmers cost almost $14 billion, of which about two-thirds was for factory-mixed feeds while the balance was mainly untreated feed grain or soybean meal.

The following will measure the energy used for processing, packaging and marketing of processed livestock feeds. The energy input into producing the grains, oilseeds, and other raw materials processed in such feeds will not be discussed here but will be treated separately in studies of crop production.

Analysis will center around the year 1977, because it is the date of the most recent Census of Manufactures, from which much of the data will be drawn. Information about energy used for capital goods, and for several other items, will be supplemented by aid of the Energy Analysis Handbook (EAH)[1/]. Without this source of information, the following analysis would be even more tentative than it now is, given the many data uncertainties. The EAH figures relate to 1967, and price indices are used to bring this information up to 1977. Supplemental information is drawn from other sources as needed. The Census of Manufactures, 1977,[2/] lists "Industry 2048, Prepared Feeds, Not Elsewhere Classified", which excludes dog, cat, and other pet foods (Industry 2047) with shipments totaling $8,350.2 million. The specifications are shown regrouped in Table 1.

Table 1. Product Shipments From Prepared-Feeds Industries, 1977

Description	$ Million	Metric Tons, Million
Poultry feeds	2,758.6	16.06[a]
Swine feeds	1,468.1	6.59
Dairy cattle feeds	1,454.1	8.04
Beef cattle feeds	970.9	6.50
Other poultry and livestock feeds, including duck, geese, horse, mule, etc.	337.9	2.22[a]
Other prepared feeds	338.0	2.53[a]
Subtotal, specifications	7,327.6	41.94
Prepared feeds not elsewhere classified, not separately known[b]	851.8	--
Prepared feeds not elsewhere classified, not separately known[c]	170.8	--
TOTAL	8,350.2	47.50[d]

a/ Assuming small miscellaneous items, specified only in dollars, to have same weight-to-dollar ratio as the bulk of the group.

b/ Typically for establishments with 10 employees or more, from which no data were obtained.

c/ Typically for establishments with less than 10 employees.

d/ Assuming unspecified quantities (footnotes a/ and b/) to be in same proportion between dollar value and weight as the specified ones.

Source: *1977 Census of Manufactures, Industry Series: Grain Mill Products, MC77-I-20D, Issued August 1980.*

The dollar total represents factory-gate cost. The farmers' expense for these goods also includes marketing costs, and so rises to about two-thirds of the farmers' total cost for purchased feedstuffs.

Specifications of materials, ingredients, containers and supplies to this industry totaled $6,697.6 million for 1977, and of direct energy $80.7 million. This leaves $1,571.9 million as value added (returns to capital, labor, and management). An estimate of embodied energy is also needed for capital, among the internal factors of production.

Factory Use of Energy. Purchased fuels and electric energy in the prepared-feeds industry is shown in the Census as 28.4 trillion BTU, costing $80.7 million. Of this total, 23.1 trillion BTU, costing $37.9 million, is for fuels (mainly fuel oil and natural gas) while the difference, 5.3 trillion BTU for $42.8 million, is for electricity. Other specifications in the same publication show that electricity was assumed to contain 3,412 BTU/kwh, which is merely the heat content of the current. Instead we will use the heat content of the fuel used both directly (in the generating plant) and indirectly (in building the plant, making its materials, etc.), as shown in the EAH. This means a coefficient of 13,885 BTU/kwh, and we obtain a sum of 21.54 trillion BTU for electricity.

Specifications for fuels are not complete. Those for oil allow us to compute the following:

Distillate fuel oil, 324.3 thousand barrels, at 5,825 thousand BTU/barrel,		= 1.89 trillion BTU
Residual fuel oil, 154.6 thousand barrels, at 6,287 thousand BTU/barrel,		= .97 trillion BTU
	TOTAL OIL	2.86 trillion BTU

or 12.4 percent of the 23.1 trillion BTU for fuel. This appears to leave 87.6 percent, or 20.2 trillion BTU for other fuels. The proportions are not unlikely; in dollar cost, oils accounted for 20 percent, other fuels 80 percent.

The other fuels must be mainly natural gas; coal is entered without numbers, in a way that indicates insignificant quantities.

As with electricity, energy cost of energy is not included in the Census totals. The breakdown just shown allows an approximate computation (based on the EAH coefficients), as follows:

Petroleum refinery products, 2.86 trillion BTU X 1.2227	= 3.50 trillion BTU
Natural gas, 20.22 trillion BTU X 1.1166	= 22.58 trillion BTU

These figures are still on the low side because they do not include costs of shipping, etc. On the basis of the above, we can now sum the on-factory used fuel and its energy cost:

Oil fuels	3.50 trillion BTU
Natural gas	22.58 trillion BTU
Electricity	21.54 trillion BTU
TOTAL ENERGY	47.62 trillion BTU

which is two-thirds higher than the sum given in the Census, and represents 5,703 BTU per dollar's worth of factory output of the industry in 1977, or 30,295 BTU per dollar of its value added.

Energy Cost of Capital. The feed processing industries are not very capital intensive, and so the embodied energy used in this way is of modest proportions. Yearly new investment is in the range of 1-2 percent of gross sales per year. Taking new investment in 1977, of $130.9 million, we can estimate embodied energy from the EAH, using the Sector "New Construction, Non-Residential" (Sector 1102) which in 1967 had an energy intensity of 75,728 BTU/$. Applying a price index of 200, which is realistic for the construction industries over the years 1967-1977, we use a coefficient of 37,864 BTU/$ in 1977 and estimate the embodied energy in 1977 new investment at 4.96 trillion BTU.

Purchased Materials. Next after direct energy (and its indirect energy cost) we consider the energy used to produce and deliver materials (feedstocks) for processing by the feed processors, and for packaging materials used by the feed processors. Table 2 summarizes data from the 1977 Census of Manufactures, with some regrouping to facilitate the analysis that follows.

Calculations based on the specified figures need to be raised in order to allow for the unspecified ones. The last two items, plus the discrepancy (note k/) add up to $1,687.7 million, or 33.69 percent of the specified ones. Thus all estimates of embodied energy inputs will be raised by a factor of 1.3369. In addition, the item "Supplements and Concentrates", shown with a cost of $28.7 million, amounts to .59 percent of the specifications other than packaging. Thus the specified items other than packaging will be raised by (1.3369 X 1.0059 =) 1.3448.

Packaging materials need explaining before the other inputs because, like capital, to some extent they apply to these other inputs as well. The packaging materials in the feed processing industries are specified as mainly paper sacks and paperboard containers, to a lesser extent as bags made of burlap, cotton, and polypropylene (textile type). Comparison of the Censuses of Manufactures 1967, 1972 and 1977 show price indices for textile bags of 155.4, of paper and fiber boxes 163.6, and of nylon textiles of .993. Applying these to the energy intensity coefficients (in EAH) of Sectors 1710, 2500, and 2801, we obtain energy intensities of 59,403, 81,547, and 244,843 per dollar's worth of these packaging materials in 1977. These calculations take no account of shifts to more energy sparing techniques in the production of each product in the meantime, but neither can we trace the countervailing tendency to shift toward more energy intensive products within each group.

The total embodied energy in the specifications of packaging materials then adds up to 9.01 trillion BTU in 1977. Raising this by the factor of 1.3369 (above), we obtain 12.05 trillion as the total estimate.

Table 2. Materials, Ingredients, Containers and Supplies Purchased by Feed Processing Industries (Industry 2048) in 1977

Description	Cost $ Million	Weight Million Metric Tons
Cereal grains[a/]	1,481.4	15.37
Processed grain products[b/]	490.2	4.86
Oilseed products[c/]	1,677.4	7.40
Brewers' and distillers' grains	64.7	.46
Sugar products[d/]	95.7	1.37
Alfalfa meal, excluding alfalfa hay	103.5	1.02
Animal products[e/]	391.4	1.50
Urea	38.5	.26
Subtotals	4,342.8	32.24
Microingredients[f/]	379.5	--
Minerals[g/]	181.0	--
Supplements and concentrates[h/]	28.7	--
Packaging materials[i/]	77.9	--
All other materials, ingredients, containers and supplies	621.0	--
Materials, ingredients, containers and supplies, not separately known[j/]	1,043.9	--
Expenses not specified[k/]	22.8	--
TOTAL	6,697.6	45.6[l/]

a/ *Wheat, corn (mainly), oats, barley, and sorghum grain.*

b/ *Wheat flour, wheat germ, wheat millfeed (mainly), corn meal, hominy feed and meal, corn gluten feed, and other millfeed and screenings.*

c/ *Cottonseed cake and meal, soybean cake and meal (mainly), other oilseed cake and meal, soybean millfeed, and fats and oils.*

d/ *Sugar (cane and beet) in terms of sugar solids, and molasses.*

e/ *Meat meal and tankage (mainly), and fish meal and solubles.*

f/ *Vitamins, drugs and antibiotics, and all other microingredients, including trace minerals.*

g/ *Minerals (except trace minerals), including calcium, phosphorus, and salt.*

h/ *Mixture of feed ingredients.*

i/ *Burlap bags (new), cotton bags, polypropylene bags (textile type), paper shipping sacks, and paperboard boxes and containers.*

j/ *Total cost of materials of establishments that did not report detailed materials data, including establishments that were not mailed a form.*

k/ *Discrepancy between total and details in the Census.*

l/ *Assuming residual items have same weight-to-price ratio as subtotals and adding an allowance for weight of minerals of 2.0% (see below).*

Feedstock Materials. In analyzing data on these materials, energy cost of feed crop production are left out in this inquiry. However, transportation and marketing costs will be included, as far as feasible.

a) *Cereal grains* are unprocessed, thus carry no energy cost to be analyzed here, except the cost of transportation and marketing. These costs will be set at one-sixth of the factory's expenses for grains, because corn (which is by far the leading kind in these data) had a marketing margin of about 20 percent (over farm price) in the years in question. This yields a figure of \$246.9 million. The EAH energy intensity coefficient for wholesale trade (Sector 6901) is 39,636 BTU/\$ for 1967. The index of corn farm price, 1967-77, comes to 197, and thus the energy coefficient for 1977 is computed to 20,120 BTU/\$. Multiplying with the dollar value above, we obtain 4.97 trillion BTU; raising this by 1.3448, the estimate is increased to 6.68 trillion.

b) *Processed grain products* come from flour mills (Industry 2041, Census of Manufactures). Using the same procedures as in the previous sections, we apply these to the dollar rather than the tonnage specifications. The reason is that these products are mainly by-products from the flour mills and are priced in these at lower rates than the same tonnage of main product. Hence, it appears prudent to distribute the energy used by and for the flour mills in these proportions. The total of \$490.2 million is raised by 1.3448 to \$659.2 million, which amounts to 17.92 percent of all product shipment from Industry 2041 in 1977. Applying this percentage to energy quantities estimated to have been used up in the flour mills, we obtain:

Fuel	4.75 trillion BTU
Grain marketing	1.50 trillion BTU
Packaging	1.24 trillion BTU
Capital charges	.36 trillion BTU
TOTAL	7.85 trillion BTU

c) *Oilseed products* come mainly from soybean oil mills and will, for simplicity, be treated as coming entirely from them (Industry 2075). The sum of $1,677.4, raised by 1.3448, becomes $2,255.8, which is 36.9 percent of product shipments from the soybean oil mills in 1977. Using again the same procedures as before, the following numbers emerge:

Fuel	26.48 trillion BTU
Soybean marketing	4.25 trillion BTU
Packaging (paper)	.24 trillion BTU
Capital charges	1.01 trillion BTU
TOTAL	31.98 trillion BTU

d) *Brewers' and distillers' grains* is a small item coming from a very energy intensive industry (Wet Corn Milling, Industry 2046). The amount shown, $64.7 million, raised by 1.3448 or $87.0 million, is 4.5 percent of the product shipments from Industry 2046. Again using the same procedures as for the preceding groups, the results are:

Fuel	5.04 trillion BTU
Marketing (corn)	.17 trillion BTU
Packaging	--- trillion BTU
Capital charges	.40 trillion BTU
TOTAL	5.61 trillion BTU

e) *Sugar products*, $95.7 million, raised by 1.3448 to $128.7 million, will have their energy cost estimated directly from the EAH rather than through the Census of Manufactures. Sector 1419 is shown with an energy intensity coefficient of 141,785 BTU/$ in 1967. The producer price index of sugar and confectionery was 177.4 in 1977 (1967 = 100), thus the energy intensity in 1977 would be 79,924 BTU/$, and the energy used for $128.7 million worth of sugar products comes to 10.29 trillion BTU. Unlike other estimates in this study, the figure includes energy used to produce the cane and beet crops from which the sugars were made.

f) *Alfalfa meal and animal products* cannot be readily traced through the industrial statistics. For simplicity, they will be treated as being close to the energy intensity of grain mill products and assigned the same (direct and indirect) energy per dollar's worth as the processed grain products, which yields a total .96 percent higher than the grain mill group, or 7.93 trillion BTU.

g) *Urea* for feed is a special product of the nitrogen fertilizer industry. The cost to the feed processors is indicated in the Census of Manufactures as $146 per metric ton. This is about 36 percent of the price farmers paid for fertilizer urea (pure N content), hence feed urea can be assumed to have about that percentage of N, which is the terms in which energy used for nitrogen production is computed. At about 45,000 BTU per pound of N (pure content) for fertilizer urea,[3/] we get about 100 million BTU per metric ton, or 36 million per metric ton of 36 percent urea. Applying this to the .26 million metric tons of feed urea, we estimate its energy requirement at 9.4 trillion BTU. Raising this by 1.3448, we obtain 12.6 trillion BTU.

h) *Microingredients.* The $379.5 million worth of vitamins, drugs, antibiotics, trace minerals and other microingredients is too complex for detailed analysis, given the absence of further specifications. Instead we use the EAH energy intensity coefficient for Drugs (Sector 2901) of 65,055 BTU/$ in 1967 prices, and reduce this by the producer price index for drugs and pharmaceuticals which is 140.5 in 1977 (1967 = 100), and obtain 46,302 BTU in 1977. Multiplying with $379.5 million we get 17.57 trillion BTU; raising this by 1.3448, the total is brought up to 23.6 trillion.

i) *Minerals.* The total of $181.0 million includes calcium, phosphorus, and salt, and excludes trace minerals. The three principal categories are known, in rough quantity, to livestock feed experts: feed phosphate and feed grade $CaCO_3$ are said to contribute 1 percent each to the weight of poultry and swine feed, and a somewhat lower percentage to cattle feed.

Specifications in Table 1 indicate that, within these three categories as specified, the former two occupy together 63.5 percent and cattle feed 36.5 percent by weight. A weighted average, for each of phosphate and calcium, would be lower than 1 percent but higher than .65 percent, and may be set at .8 percent, using the total tonnage figure in Table 1. This gives the phosphorus and the calcium feeds 380,000 metric tons each. Salt should enter the rations at 0.4 percent by weight, thus some 190,000 metric tons for the whole feed mixing industry.

These proportions and estimates can be checked against the prices of these goods. Dibasic phosphate (100 percent $CaHPO_4$) is shown in the 1977 Census of Manufactures (in Industry 2819, Industrial Chemicals Not Elsewhere Classified), jointly for feed grades and other grades except fertilizer grades. The 1977 price comes to \$177.15 per short ton, or \$195.27 per metric ton. Multiplying this with 380 thousand metric tons yields a cost of \$74.20 million.

Calcium Carbonate (precipitated, 100 percent $CaCO_3$) is shown in the same Census but without a price for 1977. Data from 1972 in the same publication allow to compute a price proportion: the carbonate price was then 69 percent of the feed phosphate price. If the same holds in 1977, we obtain a carbonate price of \$134.74 per metric ton, and the 380 thousand tons would come to \$51.20 million.

Salt is a low cost article, priced at \$10.41 per short ton in 1977, or about \$11.50 per metric ton. Cost of 190 thousand tons would be \$2.2 million.

Summing up, we have:

Phosphate	\$ 74.20 million
Calcium Carbonate	51.20 million
Salt	2.20 million
TOTAL, 3 minerals	\$127.60 million

This is considerably short of the $181 million spent by feed processors for minerals in 1977. Either there is a trade margin on the order of 40 percent, or the quantities are under specified, or there must be some other minerals not mentioned in the Census. Whichever way the data are read, it is clear that we risk to under rather than over state the energy input through mineral feed additives.

Energy inputs into these minerals are not likely to be the same. Feed phosphate, no longer shown among the fertilizer industries, is likely still to use the energy intensive furnace process which turns out a cleaner product than the less energy intensive processes now dominant in fertilizer manufacturing. According to one source, the furnace process used several times the amount of energy in the newer processes, or some 27,000 BTU per pound of P_2O_5,[4/] which comes to 59.6 million BTU per metric ton. Applying this to 380 thousand metric tons, we obtain an estimate of 22.64 trillion BTU. Since this was based on total quantity of processed feed by weight, there is no case for raising the figure, as in most of the other estimates.

For calcium and salt, there are no direct indications for individual products. Within the industry groups given in the Census, each is a small fraction, and there is no way of telling which ones might be the more, or the less, energy intensive. For lack of other indications, we take the average energy intensity of industrial chemicals which was about 200 thousand BTU per dollar in 1967; with a price index close to 200 (1967-77) for chemical products, we arrive at about 100 thousand BTU per dollar's worth of industrial chemicals in 1977. Thus the $53.40 million worth of calcium and salt bought by the feed processors in 1977, the energy used would be 5.34 trillion BTU. Together with the 22.64 trillion for phosphate, this makes 27.98 trillion for the minerals group, likely to be a low estimate.

Summary of Findings. The specifications shown in the previous sections can now be added up, as follows:

Fuel in feed factories	47.6 trillion BTU
Capital cost of feed factories	5.0 trillion BTU
Packaging in feed factories	12.1 trillion BTU
Grain marketing charges	6.7 trillion BTU
Processed grain products	7.9 trillion BTU
Oilseed products	32.0 trillion BTU
Brewers' and distillers' grain	5.6 trillion BTU
Sugar products	10.3 trillion BTU
Alfalfa meal and animal products	7.9 trillion BTU
Urea	12.6 trillion BTU
Microingredients	23.6 trillion BTU
Minerals	28.0 trillion BTU
TOTAL ENERGY, DIRECT AND INDIRECT	199.3 trillion BTU

The average now stands at 23,868 BTU per dollar's worth of processed feeds, 1977 prices.

Marketing Margins. The above relates to energy cost of processed feeds, other than the cost of component crop materials, ex-factory. To the total we may choose to add an allowance for the transportation and marketing of such feeds. Assuming the margin to be on the average 10 percent of the factory price, the marketing margin would be worth $835.02 million. The EAH gives an energy intensity coefficient for wholesale trade (Sector 6901) of 39,636 BTU per dollar's worth of its activity; with the wholesale price index for manufactured animal feeds at 204.6 in 1977 (1967 = 100), the energy intensity coefficient becomes 19,372 BTU per dollar's worth in 1977. Multiplying with $835.02 million, we obtain 16.2 trillion BTU as the energy cost of marketing. This represents an 8.13 percent addition to the 199.3 trillion at the factory gate. At the farm level, the energy coefficient per dollars' worth of expense for processed feed now stands at 21,700 BTU.

Appraisal of Results. The estimates in this study are likely to be on the low side, for a variety of reasons some of which are mentioned above. Transportation and marketing overheads have not been traced at all levels; cross-hauls between factories are impossible to pin down, among other things because some of them are likely to be included in the energy budgets of individual industries while others are not. And whenever there was a choice, the lower alternative was chosen, on purpose--it is better to be on the low side and know it than to attempt a precise balance and then not know on which side the estimates are. In this way, these estimates should remain useful for some time, even after the factories have made some immediately feasible improvements in their use of energy. Large technological breakthroughs can of course not be anticipated, nor should that be attempted lest the estimates are lost in conjecture.

Improvement in the energy efficiency of each process is not all there is to energy saving, however. The study serves to emphasize the large proportion of indirect energy in many factory products. Direct energy used in the feed mixing factories, as reported in the Census of Manufactures, amounts to only about 13 percent of the final figure shown in this study for the farm-gate energy cost of prepared feeds, still without crop production energy costs; when the latter are included, on-factory energy cost becomes an even much smaller fraction of the total. This should serve to illustrate the need for analyses of indirect energy use: changes in the mix of raw materials and intermediate products may have more influence on total energy consumption than any savings of energy directly in each production process. The case of pesticides illustrates this point.[5/] In this study, the large role of chemical additives (urea, microingredients and mineral feed supplements) reinforces the same conclusion. These ingredients together take over 30 percent of the specifiable energy budget for prepared feeds (still without crop production energy costs). The choice of these and other materials will influence the total energy budget (either upward or downward) in ways which could not be pursued in this study.

Energy in Crop Production. All of the preceding relates to energy costs other than those of the grains, oilseeds, alfalfa and animal products that enter the feed processing; only the sugars had their crop production energy requirement implicitly included. For any combination of the above findings with crop energy requirement data (which vary with seasons, regions, and future technology), the following proportions between the principal crop components can be set forth, based on the 1977 Census of Manufactures and subject to revision by any subsequent Census data.

Crop	Percent of Feedstock *(tonnage basis)*
Wheat (mainly bran)	13.3
Corn	45.1
Other coarse grains	10.4
Oilseeds (mainly soybeans)	24.9
Sugar products	6.3
TOTAL	100.0

This separation of crop data from manufacturing data should help making subsequent calculations more flexible. The crop energy requirements are generally larger than those shown above for processing and marketing energy requirements, either per unit of weight or value of both unprocessed crops and of processed feeds. Estimating them separately is therefore essential.

Footnotes

1/ EAH = Clark W. Bullard, Peter S. Penner and David A. Pilati, Net Energy Analysis: Handbook for Combining Process and Input-Output Analysis, University of Illinois at Urbana-Champaign, Energy Research Group, Center for Advanced Computation, CAC Document 214, October 1976. Further information in David Simpson and David Smith, Direct Energy Use in U.S. Economy 1967, CAC Technical Memo No. 39.

2/ 1977 Census of Manufactures, Industry Series for Several Industries, and Subject Series for Fuels and Electric Energy Consumed, U.S. Department of Commerce, 1980.

3/ Folke Dovring and Donald R. McDowell, Energy Used for Fertilizers, UIUC Agricultural Economics Staff Paper 80 E-102, February 1980, p. 13.

4/ Charles H. Davis, Energy Requirements for Alternative Methods for Processing Phosphate Fertilizers. Presented at Technical Conference of International Superphosphate and Compound Manufacturers Association Ltd., Prague, Czechoslovakia, September 23-27, 1974, p. 9.

5/ Folke Dovring and Donald R. McDowell, Energy Used for Pesticides, UIUC Agricultural Economics Staff Paper 80 E-150, December 1980, pp. 8-9.