ENERGY ACCOUNTING: THE CASE OF FARM MACHINERY IN MARYLAND

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APPROACHES TO FARM MACHINERY ENERGY ACCOUNTING

Farm machinery energy accounting has taken basically three approaches.

The first approach is concerned with the energy embodied in farm machinery on a national basis. Two studies have attempted to show the aggregate amount of energy embodied in the manufacture of farm machinery. Using input-output analysis, Bullard et al. provide estimates of the energy costs of goods and services for 1967. Measured in BTUs per dollar of final product, the energy cost of farm machinery at 1967 price levels is given as: coal, 34,478 BTUs; natural gas, 24,794 BTUs; refined oil, 12,541 BTUs; and electricity, 5,396 BTUs.

The Department of Commerce in its *1972 Census of Manufacturers* presents data on quantity of purchased fuels burned for heat and power by industry group and industry. For farm machinery manufacturing, the data given for 1971 are: fuel oil, 194,800 barrels; bituminous coal, lignite, and anthracite coal, 204,000 short tons; natural gas, 17.4 billion cubic feet.

A second approach to farm machinery energy accounting is concerned with the amount of energy expended powering farm machinery (but not including embodied energy).[1] The USDA and the Federal Energy Administration have jointly published a national agricultural energy data base for 1974 which contains, among other things, detailed estimates by states of the fossil fuel energy used in powering on-farm activities. Their estimates are available by type of fossil fuel and are broken down by crop and livestock product as well as by type of farm activity (e.g. preplanting, planting, cultivation).

The third approach to farm machinery energy accounting is concerned with the machinery-related energy involved in the production of one crop, namely field corn. Pimental assumed that the energy embodied per ton in an automobile was a reasonable proxy for the energy embodied per ton in farm machinery. Combining the estimates for energy embodied in farm machinery with estimates of gasoline and electricity used on a corn farm, Pimental arrived at a per-acre estimate of the machinery energy cost of producing corn.

Doering obtained from a farm machinery manufacturer (John Deere) estimates of the energy requirements for producing various types of farm machinery. The Doering estimates are only for energy value added in manufacturing and do not include the energy required in manufacturing the steel in the first place on the grounds that the steel can be recycled eventually. Using the Deere energy data, Doering found the machinery energy requirements per acre of corn to be only one third those found by Pimental (129 vs. 384 kcal $\times 10^6$).

Doering includes several useful estimates of the (value added) energy expenditure per ton of selected items of farm machinery. Nevertheless, at the end of the article, Doering notes that, "If one is to make sense of energy analysis of agriculture, the data for equipment must be handled on a disaggregated basis, implement by implement." We therefore provide a more complete, disaggregated agricultural equipment energy analysis than has been published previously. Maryland is used as a case study. The analytical technique described here could be applied to any state, although the results of the analysis would differ among states.

METHOD

We first estimate the fossil fuel energy embodied in Maryland farm machinery by type of machine. Then a method of allocating the fossil fuel energy embodied per machine among the various crop and livestock uses of that machine is developed and applied. The results of this energy allocation are combined with esti-

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[1]In this article, fossil fuel energy that is consumed in a process, such as burning gasoline in a tractor, is called energy *expended.* However, once energy has been expended in a process, the energy thus expended becomes a quality of the resulting product. Such energy is called *embodied* energy. Thus, the coal used in manufacturing farm equipment is called embodied energy when we account for the use of this energy on Maryland farms. A third word was needed to cover the end-of-the-year accounting of the mix of expended and embodied energy used in 1974. We chose energy *used* to connote this mix of embodied energy and energy expended.

mates of the fossil fuel expended on the various items of machinery while in operation on the farm to show the machinery energy used in producing various crop and livestock products. Farm machinery energy requirements are compared with other agricultural energy requirements in Maryland. Because of the availability of census data, 1974 is used as the year of analysis.

ENERGY EMBODIED IN AGRICULTURAL MACHINERY

Estimates of the fossil fuel energy embodied in machinery were made for the 20 most important types of farm machinery (as measured by value of machine) found on Maryland farms.

Because of the availability of manufacturing energy value added data from the John Deere Company, a commonly used item of John Deere equipment was taken to be representative of that class of farm machinery.[2] For most items, the 1974 census of agriculture provided information on the number of pieces of machinery on farms, although estimates had to be made for some items. For purposes of this study the energy expended making the steel used in the machinery was added to value added energy costs of machinery fabrication on the grounds that, although farm equipment can be recycled to the steel mill as scrap, most machinery remains on the farm indefinitely.

Separate energy estimates were made for parts included on the machinery but not accounted for in the manufacturer's energy expenditure estimates.

Additionally, an estimate for spare parts used in repair was made. On the basis of the Internal Revenue Service depreciation guideline (*U.S. Master Tax Guide*), a 10-year life for each machine was assumed. It was further assumed that on the average 5 percent of the energy originally embodied in steel would be replaced over the 10-year period. However, the parts most frequently replaced, e.g. the carburetor, require more extensive fabrication per pound than the longer lasting parts, e.g. the frame, so 10 percent of the original value added in manufacturing was assigned as the energy cost of fabricating repair parts.

An average tire life of five years was assumed. Thus the energy cost of manufacturing two sets of tires per item of wheeled equipment was added to the embodied energy figures.

The results of this analysis are given in Table 1.

TABLE 1. FOSSIL FUEL ENERGY EMBODIED IN AGRICULTURAL MACHINERY BY TYPE OF MACHINE, MARYLAND, 1974

Machine Type	Units on farm	Total energy embodied in machinery	Embodied energy per year	Percentage of total
		- Billion Calories -		
Tractors (JD 4230)	34,705	2,746.90	274.69	41.5
Farm Trucks (including pick-up)	21,307	1,093.67	109.37	16.5
Discs (20 foot, 16" blades)	18,200	750.79	75.08	11.3
Farm Automobiles	16,276	473.26	47.33	7.1
Moldboard Plows (5 - 16" bottoms)	18,200	281.54	28.15	4.3
Combines (JD 4400)	2,740	216.94	21.69	3.3
Milking Equipment (Mueller, Clay)	3,066	195.19	19.52	2.9
Planters (JD 1250-4)	15,163	161.46	16.15	2.4
Manure Spreaders (JD-34)	9,870	108.05	10.81	1.6
Balers (JD 24T)	5,159	91.82	9.18	1.4
Drills and Seeders (JD B-B)	7,937	91.68	9.17	1.4
Farm Loaders (JD 48)	9,870	86.45	8.65	1.3
Corn Pickers and Picker-Shellers (JD 237)	2,802	81.68	8.17	1.2
Hay Conditioners (JD 483)	3,614	64.44	6.44	1.0
Forage Harvesters (JD 38)	2,603	44.02	4.40	0.7
Brooding Equipment (Beacon B-6)	70,655	37.58	3.76	0.6
Corn Heads (JD 443)	1,954	36.71	3.67	0.6
Windrowers (JD 290 PTO)	1,472	22.73	2.27	0.3
Forage Blowers (JD 65C)	2,603	22.45	2.24	0.3
Grain Dryers (Mathews 400 B-10)	468	18.63	1.86	0.3
Total		6,625.99	662.60	100.0

Note: Details of the calculations and sources involved are given in Table C-1 of Foster, Phillips, *Fossil Fuel Energy Used in Agriculture, A Data Base for Maryland—1974.*

ALLOCATING ENERGY EMBODIED IN MACHINERY AMONG ALTERNATIVE CROP AND LIVESTOCK USES

In some cases all of the energy embodied in a piece of equipment could be allocated to one crop or livestock use: corn pickers to corn production, for example. But items such as farm automobiles, farm trucks, and tractors are used in the production of every farm commodity and other pieces of farm machinery are used on some, but not all, farm commodities: moldboard plows are used in all *crop* production but are not directly chargeable to any of the *livestock* operations.

It therefore seemed appropriate to distribute the energy embodied in a piece of equipment used in producing more than one commodity among those commodities on which it is used. To give heavier weight to those farm activities on which the equipment is used most heavily, the embodied energy of each machine used in producing more than one commodity was allocated among those commodities on a prorata basis with the assignment proportional to the calories of gasoline and diesel fuel spent on powering the activities associated with the

[2]This technique has the disadvantage that Deere may not fairly represent the farm machinery manufacturing industry. In fact, the data used may no longer even represent Deere's costs. Recent correspondence with the company points out that since the cost of energy started its dramatic rise they have been successful in significantly reducing the use of energy in their manufacturing plants. However, the data have the advantage of being more likely to represent farm machinery manufacturing industry energy costs than does a proxy such as the energy costs of manufacturing an automobile—a technique that researchers were forced to use before the advent of the Deere data.

production of those commodities. The resulting allocation of fossil fuel energy embodied in farm machinery for selected commodities produced in Maryland is shown in Table 2.

TABLE 2. FOSSIL FUEL ENERGY EMBODIED IN FARM MACHINERY PER YEAR BY TYPE OF MACHINE AND BY SELECTED COMMODITY ASSOCIATED USE OF MACHINE, MARYLAND, 1974

Farm machinery[a]	Fossil fuel energy embodied in machinery[b]	Field corn	Wheat	Alfalfa	Broilers	Milk
	- - - - - -	- - - -	Billion Calories	- - - -	- - - -	- - - -
Farm Automobiles	47.33	14.29	2.90	1.99	1.84	3.17
Farm Trucks	109.37	33.03	6.67	4.59	4.26	7.33
Tractors	274.69	82.96	16.76	11.54	10.71	18.40
Farm Loaders	8.65	2.61	.53	.35	.34	.58
Moldboard Plows	28.15	10.14	2.05	1.41	-	-
Discs	75.08	27.03	5.48	3.75	-	-
Planters	16.15	5.82	1.18	.81	-	-
Drills and Seeders	9.17	3.31	.67	.46	-	-
Manure Spreaders	10.81	-	-	-	2.63	4.55
Hay Conditioners	6.44	-	-	4.95	-	-
Balers	9.18	-	-	7.06	-	-
Windrowers	2.27	-	-	1.75	-	-
Combines	21.69	11.24	2.27	-	-	-
Corn Heads	3.67	3.67	-	-	-	-
Corn Pickers and Picker Shellers	8.17	8.17	-	-	-	-
Forage Harvesters	4.40	-	-	-	-	-
Forage Blowers	2.24	-	-	-	-	-
Grain Dryers	1.86	1.44	.10	-	-	-
Brooding Equipment	3.76	-	-	-	3.76	-
Milking Equipment	19.52	-	-	-	-	19.52
Total	662.60	203.71	38.61	38.66	23.54	53.55

[a]The energy embodied in the production of farm automobiles, farm trucks, farm loaders, and tractors was allocated to each crop and livestock product in proportion to the percentage of total energy in gasoline and diesel fuels expended on the production of each crop and livestock product. The energy embodied in the production of plows, discs, planters, drills and seeders was allocated to crops only, in proportion to the percentage of total energy in gasoline and diesel fuels expended on crop production. Similarly, the energy embodied in the production of the other types of farm machinery listed was allocated among the appropriate crops and livestock products in proportion to the percentage of the total energy in gasoline and diesel fuels expended in their production. Details of the allocation procedure are explained in Table C-2 of Foster, Phillips, *Fossil Fuel Energy Used in Agriculture, A Data Base for Maryland—1974.*

[b]From Table 1.

ENERGY EXPENDED POWERING FARM MACHINERY BY COMMODITY

A USDA/FEA study provided data on the amount of gasoline, diesel fuel, fuel oil, propane gas, natural gas, and electricity spent producing various farm commodities in the State of Maryland. We expanded this list by making a separate estimate for pasture, which was not included in the USDA/FEA list of commodities. Kilowatt hours of electricity were converted to calories and the result was multiplied by three to obtain an estimate of the fossil fuel calories required to produce that amount of electricity.

The procedure described provided an estimate of the fossil fuel energy expended in powering on-farm activities in Maryland by commodity produced. Because about 6.5 percent of the energy expended powering farm activities goes to nonmachinery uses such as lighting, water heating, space heating, and electrical overhead, the figures were scaled downward to account for these nonmachinery types of on-farm power expenditures. The result is shown in the middle column of Table 3.

TABLE 3. FOSSIL FUEL ENERGY EMBODIED IN AND USED TO POWER FARM MACHINERY, MARYLAND, 1974

Commodity	Energy embodied in farm machinery per year[a]	Energy expended in powering farm machinery[b]	Total
	- - - - - -	Billion Calories	- - - - - -
Field Corn	203.71	453.53	657.24
Soybeans	81.03	151.61	232.64
Corn Silage	39.32	64.56	103.88
Tobacco	14.73	38.90	53.63
Winter Wheat	38.61	73.64	112.25
Other Hay	11.77	19.80	31.57
Vegetables for Processing	39.04	82.60	121.64
Alfalfa Hay	38.66	64.43	103.09
Vegetables for Fresh Market	10.73	22.15	32.88
Barley	29.12	56.22	85.34
Apples	6.52	12.45	18.97
Sweet Potatoes	1.27	2.83	4.10
Peaches	2.27	4.37	6.64
Oats	7.67	14.50	22.17
Potatoes	1.14	1.75	2.89
Rye	20.32	37.87	58.19
Pasture	9.49	18.26	27.75
Miscellaneous	1.83	4.98	6.81
Total Crops	557.23	1,099.22	1,656.45
Broilers	23.54	333.55	357.09
Dairy	53.55	238.29	291.84
Beef	15.21	39.95	55.16
Hogs	8.14	33.69	41.83
Chickens	3.03	22.21	25.24
Sheep	.99	1.81	2.80
Turkeys	.45	.21	.66
Horses, Miscellaneous Livestock[c]	-	-	-
Miscellaneous Poultry	.46	1.21	1.67
Total Livestock	105.37	670.94	776.31
Total Crops and Livestock	662.60	1,770.15	2,432.75

[a]From Table 1.

[b]From Foster, Phillips, *Fossil Fuel Energy Used in Agriculture, A Data Base for Maryland—1974,* Md. Ag. Expt. Sta. M.P., in process, Table B-1. The data in Table B-1 are scaled downward to account for the fact that 6.594 percent of the energy accounted for in that table (B-1) is not attributable to farm machinery.

[c]Data for energy embodied in farm machinery and expended in powering farm machinery are not available for Horses and Miscellaneous Livestock.

MACHINERY ENERGY USED PER COMMODITY

By adding the annual fossil fuel energy embodied in farm machinery from Table 2 to the energy expended annually powering farm machinery, we obtained an estimate of the machinery energy used in Maryland by agricultural commodities (Table 3).[3]

The result of these calculations can be used to compare energy spent for farm machinery with other uses of energy in agriculture. This comparison is shown in Table 4.

[3]Because most of the tonnage of crops raised in Maryland is fed to Maryland livestock, most of the energy attributed to crops in Table 3 is ultimately chargeable to livestock. For example, an accounting of all the machinery energy used producing broilers would ultimately have to include the machinery energy used in producing the feed fed to broilers. Such an accounting is available in Foster et al.

TABLE 4. FOSSIL FUEL ENERGY EMBODIED IN AND USED TO POWER FARM MACHINERY VS. OTHER FARM USES OF ENERGY, MARYLAND, 1974

Category of use	Billion Calories	Percentage of total
Energy for farm machinery		
Energy embodied in farm machinery[a]	662.60	15.8
Energy expended in powering farm machinery[b]	1,770.14	42.3
Sub total	2,432.74	58.1
Energy for other agricultural uses[c]		
Transportation and processing of livestock feeds	648.75	15.5
Energy used in miscellaneous farm operations	124.98	3.0
Energy embodied in fertilizers	909.18	21.7
Energy embodied in pesticides	70.91	1.7
Sub total	1,753.82	41.9
Total	4,186.56	100.0

[a]From Table 1.
[b]From Table 3.
[c]From Foster, Phillips, *Fossil Fuel Energy Used in Agriculture, A Data Base for Maryland—1974,* Table A-4.

CONCLUSIONS

In 1974, 58 percent of the energy used in producing agricultural commodities in Maryland was accounted for by farm machinery. More energy was expended in powering farm machinery than was embodied in the farm machinery depreciated that year (Table 4).

Tractors alone account for more than 40 percent of the energy embodied in farm machinery in Maryland. Tractors, farm trucks (including pickup trucks), and discs together account for almost 70 percent of the energy embodied in farm machinery (Table 1).

More machinery energy is used raising crops than is used directly on raising livestock, but much of the machinery energy devoted to crop production is used on crops that will later be fed to animals (Table 3).

Although results would differ among states, the method of farm machinery energy accounting described here could easily be applied in other states. Generally the same data sources as are used here could be used in farm machinery energy accounting for other states.

Because farm machinery accounts for such a large proportion of the energy devoted to agricultural production, it is important to account carefully for energy associated with farm machinery use when studying energy use in agriculture. And because embodied energy makes up a significant proportion of the total energy used in agricultural production, it is important to account carefully for this use of energy.

The results of the energy accounting described here could be combined with an accounting of other farm energy requirements (energy embodied in fertilizers and pesticides, for example) to provide estimates of the energy requirements of producing all of the major Maryland farm commodities. These energy requirements could then furnish the basis for calculating the energy output/input ratios for Maryland agricultural commodities and thus provide an estimate of relative energy efficiency in agricultural production. Furthermore, once the latter estimates were available it would be possible to multiply the calories of fossil fuel used by the price per calorie and compare the result with the farm gate price of the commodity produced to give the proportion of the farm gate price attributable to energy. This proportion would be useful in making estimates of the probable production responsiveness of that commodity to future changes in the price of the fossil fuel inputs involved in its production.

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U.S. Master Tax Guide, 1978. Commerce Clearing House, Inc., Nov. 1977, p. 430.