ENERGY USE AND CONSERVATION IN THE POULTRY AND EGG INDUSTRY

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ENERGY USE AND CONSERVATION IN THE POULTRY AND EGG INDUSTRY. By George B. Rogers, Verel W. Benson, and Donald L. Van Dyne, Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 354.

ABSTRACT

Estimates of energy use in the poultry and egg industry are discussed by commodity, type of fuel, season, and function. In 1974, the 146.5 trillion Btu's used in poultry production and marketing cost producers almost $550 million. Although the efficiency of energy use in this industry has increased in the last decade, energy conservation measures discussed in this report can yield further substantial savings. Development and implementation of new technologies may reduce the use of critical forms of energy in the future. This study is intended to provide a basis for further energy research in the poultry and egg industry and to serve as a prototype for similar energy studies on other agricultural industries.

KEYWORDS: Broilers, conservation, eggs, energy, layers, marketing, production, turkeys.

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E R R A T A

The following changes should be made in the publication Energy Use and Conservation in the Poultry and Egg Industry, Agr. Econ. Rep. No. 354, published by the Economic Research Service:

p. 28, table 14, under Year and State applicable, 1974, Northern California should read:

North Carolina

p. 31, table 15 should read:

Table 15--Energy use per dollar of output, United States, by selected manufacturing industry and selected year (per constant 1967 dollar of shipment)

Industry	1958	1967	1975	1980
		1,000 Btu's 1/		
Prepared Feeds	7.3	10.2	11.2	12.0
Corrugated and solid fiber boxes	11.6	10.0	9.9	9.9
Plastic materials and resins	70.3	37.4	27.0	21.4
Hydraulic cement	390.0	371.0	321.0	294.0
Ready-mixed concrete	8.5	13.9	19.5	22.6
Building paper and board mills	151.6	118.5	155.0	140.0
Pulp, paper, and paperboard mills 2/	--	3/24.9	19.9	16.2

1/ Useful energy basis.
2/ 1,000 Btu's per pound of output.
3/ 1971.

CONTENTS

APPROXIMATE ENERGY CONVERSION FACTORS

Conventional units	British thermal units (Btu's)*
Kilowatt-hour (kWh)	3,413
Gallon of gasoline	125,000
Gallon of diesel fuel	140,000
Gallon of L.P. gas	95,000
Gallon of No. 2 fuel oil	140,000
Cord of wood (3/4 ton)	16,000,000
Barrel of crude oil (42 gallons)	5,800,000
Ton of coal	25,000,000
Therm of natural gas	100,000
Cubic foot of natural gas	1,000

*In practice, Btu's per unit may vary slightly.

SUMMARY

The poultry and egg industry has grown into a large-scale, economically efficient provider of reasonably priced, high-quality products. This growth occurred during a time when energy was cheap and abundant, and labor and other resources were becoming more costly and less abundant. Thus, production and marketing firms tended to substitute energy-intensive methods for those which required more labor, feed, and other resources.

Substantial quantities of various types of energy are required by the poultry and egg industry. In 1974, energy expenditures amounted to almost $550 million for the 146.5 trillion Btu's used in poultry production and marketing. The production of poultry and eggs required 195 million gallons of propane, 49 million therms of natural gas, 9 million gallons of fuel oil, 33,000 tons of coal, 31 million gallons of gasoline and diesel fuel, and 1.4 billion kilowatt-hours of electricity. These energy sources cost producers about $126 million, or 2 percent of gross farm income from poultry and eggs.

Brooding of poultry accounted for about 71 percent of the energy used in production; lighting and ventilation accounted for 11 percent; and waste handling, hauling, and operating feeding equipment accounted for almost 18 percent. Rates of energy use per 1,000 birds varied greatly with types of poultry, among regions, and among individual producers. Climatic conditions and seasonal variations in temperatures caused some differences, but these were often modified by housing design, types of equipment, and alternative management practices.

Marketing activities in 1974 required about 6 billion kilowatt-hours of electricity, 400 million gallons of heating fuels (propane equivalent), and 400 million gallons of motor fuels. These cost about $421 million, or 9 percent of the difference between farm and retail values. Of this cost, 15 percent was used for assembly, 26 percent for processing and packing, 7 percent for further processing and delivery, 16 percent for long-distance transportation, 15 percent for wholesaling, and 22 percent for retailing.

Energy use per head of poultry for production activities has declined slightly since the midsixties, as more efficient use of heating fuels, particularly for broilers, was more than sufficient to offset larger requirements for electricity, particularly for layers and turkeys. The efficiency of energy use in marketing improved between the midsixties and 1974 due to economies of scale, larger units and equipment, more direct marketing channels, and increased density of supply areas.

Because the poultry and egg industry is heavily dependent on gas and petroleum, it is sensitive to shortrun and longrun shortages, and vulnerable to increased prices. Some regions are particularly dependent upon propane and natural gas. Electricity needs for poultry and egg production and marketing, as well as for other purposes, peak during the summer months.

Growing concerns about rising energy prices and limited supplies suggest a need for improved energy management. Improved energy records are an essential starting point for energy conservation programs.

The potential for energy and dollar savings is substantial. In individual cases, energy use in production may be reduced 20 to 50 percent through such practices as partial house brooding, winterizing side curtains, reducing light intensity, reduced lighting schedules, intermittent feeding and lighting, improving maintenance practices, and using more energy efficient equipment. Management and equipment changes in marketing can also reduce energy use substantially.

In the long run, the poultry and egg industry may make greater use of alternative forms of energy, recapture more waste heat, and modify some present practices in order to save on some current forms of energy. Many topics deserve study, including more rail and combined-mode transportation, simplified packages and containers, irradiation preservation, decentralized distribution, onsite power generation, and energy parks. However, the ability of the poultry and egg industry to adopt alternative methods depends on resolving conflicts between regulatory programs and obtaining consumer acceptance of any changes in product form.

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by
George B. Rogers, Verel W. Benson, and Donald L. Van Dyne 1/

INTRODUCTION

The growth and development of the poultry and egg industry into a large-scale, efficient provider of reasonably priced, high-quality products of variety and convenience largely occurred while energy was cheap and abundant. During this period, increased amounts of energy were required and were usually available, except for wartime shortages of motor fuels.

Although total quantities of energy used in poultry and egg production and marketing have increased, this has not been universally true for each function. Some functions have substantially changed in form or extent of use. But efficiency in the use of energy has not necessarily declined or remained constant. In many instances, poultry production now requires less energy per unit of output than it did before.

Many of the changes in the poultry and egg industry over the past few decades have been the result of adopting laborsaving technology. Substitution of mechanization for manual operations may require more energy in total, but often the enhanced scale of operations results in more efficient use of energy. Although structural changes in this industry have variously affected energy use, energy was not the major motivation for the changes. Energy costs were either not considered large enough to be separately evaluated in many earlier studies or were subsumed under functional categories.

The growing concerns about rising energy prices and limited energy resources provide ample reason to identify and examine current energy use requirements and costs. This report (1) describes the uses of various forms of energy in poultry and egg production and marketing, (2) evaluates the quantitative energy requirements and their importance in terms of production and marketing costs, (3) discusses the possibilities for conserving the use of energy, and (4) suggests possible longer range adjustments which should be considered as additional increases occur in energy prices and as relative supplies of conventional energy forms continue to decline.

DEFINITIONS AND PROCEDURES

Most of the data and discussions in this report relate to direct energy used in the production and marketing of poultry and eggs. Such energy

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includes fuels used in providing heat for brooding, maintaining building temperatures, warming water, and evaporating moisture; electricity for lighting, ventilating, running equipment, and operating processing lines and pumps; and motor fuels for transportation and waste disposal. Inputs acquired by the poultry and egg industry already contain large amounts of embodied energy. Such inputs include feed, chicks and poults, machinery, supplies and building materials, containers and packaging supplies, vehicles, chemicals, and refrigerants. Nutritionists use caloric energy as one measure of the value of rations. Other scientists measure the energy expended by labor. In this sense, increased mechanization of the poultry and egg industry has substituted fuel and electricity for human energy.

Dollar costs of energy per unit of production or marketable product can vary widely from one area to another because energy prices are not standardized. It is not uncommon for electricity, natural gas, or coal prices to be more than twice as high in one area as in another, or for substantial, but smaller price ratios to exist on propane and motor fuels.

No comprehensive studies of the quantities of direct energy used in poultry and egg production had previously been made. Thus, one objective of a cooperative study by the Economic Research Service (ERS) and the Federal Energy Administration (FEA) was to determine energy use for all agricultural commodities in 1974, by energy form, function, and month. Another phase of the ERS-FEA study involved the identification of ways by which energy can be conserved.

Data for delineating quantities of energy used in poultry and egg production came largely from schedules obtained from the special contacts made with industry firms under cooperative agreements between ERS and the Georgia, Missouri, and Pennsylvania agricultural experiment stations. Some previous studies by State and Federal agencies also contained contributory quantitative and cost information. Information from Extension Service and experiment station personnel was particularly helpful in determining types of energy and housing, proportions of environmentally controlled and conventional housing, range versus confinement operations, and energy practices in many States. Estimates were developed by type of poultry for selected States, energy types, and months, and were then expanded by formulas to other States. Preliminary State estimates were designed to reflect average rates of usage and typical practices and equipment components.

No similar effort as that undertaken by ERS and FEA for agricultural production has yet been initiated for agricultural marketing. Yet, energy used in marketing is larger in total than energy used in production. A recent study estimated the costs per unit for energy and other items used in egg, broiler, and turkey marketing from product assembly through retail outlets (36). 2/ Energy use in producing processed eggs and further processed poultry products was estimated by updating cost information from earlier studies (49, 35). Relatively little information is currently available on the quantities of energy used in marketing by type although some preliminary information is

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2/ Underscored numbers in parentheses refer to references cited at the end of this report.

available from cooperative agreement surveys. Quantities of energy used in marketing were largely derived from dollar costs, using estimated U.S. average prices and price indexes.

To the extent that energy conservation practices can be encouraged and adopted, some shortrun relief of pressure on energy supplies and prices can result. Recently, many studies relating to energy conservation in poultry and egg production have been initiated or completed. These have been summarized in a conservation guidebook prepared by ERS for FEA (5). Similar opportunities for energy conservation may exist in marketing. In the longer run, changes toward different forms of energy or changes in methods can provide additional help in meeting the energy crisis. Some examples are included of shortrun conservation possibilities and longer range adjustments based on available research information.

ENERGY USE IN PRODUCTION

Amounts and Costs

In 1974, poultry and egg production in the United States consumed 195 million gallons of propane, 49 million therms of natural gas, 9 million gallons of fuel oil, 33,000 tons of coal, 31 million gallons of gasoline and diesel fuel, and 1.4 billion kilowatt-hours (kWh's) of electricity (table 1). This represented almost 33.6 trillion Btu's. Poultry production consisted of 3.1 billion broilers, 140 million turkeys, 285 million chickens, 29 million other poultry, and the eggs from 285 million hens. The value of energy used in poultry production was about $126 million, or about 2 percent of gross farm income from poultry and eggs.

Table 1--Energy use in poultry production, by type, United States, 1974

Item 1/	Propane	Natural Gas	Fuel oil	Coal	Gasoline	Diesel	Electricity
	Million gallons	Million therms	Million gallons	1,000 tons	Million gallons		Million kWh
Broilers	122.3	23.9	6.4	18.9	6.2	---	504.1
Turkeys	42.4	12.4	0.5	6.2	5.3	1.6	66.9
Hens	5.1	2.7	0.5	---	9.6	1.8	828.8
Chickens	23.6	5.8	1.2	6.1	5.7	0.9	14.3
Other poultry	1.6	4.5	.2	1.5	0.6	---	1.8
Total 2/	194.9	49.3	8.8	32.7	27.3	4.2	1,415.9

1/ Turkeys and hens include breeders; chickens mainly include laying flock replacements, but also some nonbroiler meat chickens; and other poultry includes ducks, geese, guineas, game birds, etc.
2/ Totals may not add because of rounding.

Based on propane, electricity, and gasoline, estimated energy costs in 1974 were about 1.9 cents per head of live broilers, or about 0.5 cent per pound; about 15 cents per head of live turkeys, or about 0.75 cent per pound live weight; about 11 cents per laying hen or about 0.6 cent per dozen eggs; and about 4 cents per head of nonbroiler chicken and miscellaneous poultry, such as ducks and game birds. These costs per unit were about 50 percent higher than in the midsixties for chickens and miscellaneous poultry, and about 300 percent higher for turkey and egg production.

Although price per unit of energy in 1974 was about double levels in the midsixties, the value of energy used in poultry and egg production by 1974 was over 2-1/3 times the levels of that period. There was an increase in poultry meat production of over 35 percent, but egg production remained about the same as in the midsixties. Although energy use efficiency in producing chickens has increased, adoption of new methods in turkey and egg production have increased energy requirements per head. In the aggregate, the quantity of energy used in poultry and egg production was probably less than a fifth higher by 1974 than in the midsixties.

Regional Use of Energy by Type of Poultry

The South Atlantic and South Central regions produce almost 89 percent of the Nation's broilers, with a smaller percentage in most other regions. The North Central region produces 43 percent of the Nation's turkeys, and the South Atlantic, Pacific, and South Central regions follow in importance. Laying hens and other chickens, mainly pullets for laying flock replacements, are somewhat more generally distributed than other types of poultry. More than 25 percent of the laying hens are located in the North Central region, and almost another 25 percent in the South Central region. The South Atlantic and Pacific regions are also of major importance. The regional distribution of other poultry is mainly influenced by the concentration of duck production in the Middle Atlantic and East South Central regions.

The quantity of Btu's used in poultry production tends to reflect the total number of head of various poultry produced, with the South Central and South Atlantic regions the largest energy users. The North Central and Pacific regions are the third and fourth largest users of energy, respectively (table 2).

Actual amounts of energy used by regions are also influenced by differences in climatic conditions, housing types, management practices, degrees of mechanization, proportion of various types of poultry, and varying levels of efficiency in present energy use. There are also regional differences in the relative importance of various forms of energy.

Of the total amount of energy used for poultry production, the South Atlantic and South Central regions, combined, used almost half of the gasoline and diesel fuel, over two-thirds of the propane, over half of the electricity and natural gas, and over two-thirds of the coal. The North Central region is the largest user of gasoline and diesel fuel, and is also the third largest user of propane and electricity. The Pacific region is the second largest

Table 2--Poultry produced and energy used in production, by region and United States, 1974

Item	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	United States
					Million head					
Number of--										
Broilers produced	82.1	68.0	36.7	38.6	1,280.5	707.0	766.1	0	125.6	3,104.6
Turkeys produced	.3	3.4	17.0	43.2	28.5	0	19.2	7.5	20.7	139.8
Layers, average on hand	14.5	26.6	38.0	33.5	60.9	27.9	30.8	6.5	45.9	284.6
Other chickens produced	14.5	25.8	37.7	37.5	62.5	27.8	39.6	6.3	32.8	284.5
Other poultry raised	.6	8.4	7.9	1.5	4.1	.6	3.0	.2	2.9	29.2
					Billion Btu's					
Energy used in producing--										
Broilers	542.1	433.7	242.9	242.3	6,786.1	3,644.9	4,696.7	0	833.0	17,421.7
Turkeys	11.9	111.4	665.5	2,553.5	852.3	1.4	727.2	377.9	1,145.3	6,446.4
Layers	292.2	516.6	616.2	514.2	955.1	427.8	520.4	124.9	1,102.8	5,070.2
Other chickens	196.6	341.7	554.9	587.2	682.0	325.5	536.8	112.1	589.5	3,926.3
Other poultry	6.5	372.8	163.6	19.4	47.2	7.9	44.2	2.8	80.2	744.6
Total	1,049.3	1,776.2	2,243.1	3,916.6	9,322.7	4,407.5	6,525.3	617.7	3,750.8	33,609.2

user of natural gas and fuel oil. The Middle Atlantic region is a large user of coal. New England is the largest user of fuel oil, accounting for nearly half of the total (table 3).

Table 3--Energy use in poultry production by regional percentage of U.S. total, 1974

Region	Propane	Natural gas	Fuel oil	Coal	Gasoline and diesel	Electricity
			Percent			
New England	0.4	0.0	47.2	0.0	3.4	5.4
Middle Atlantic	3.5	6.2	6.0	15.6	6.6	8.1
East North Central	6.7	1.4	5.2	6.1	11.3	8.9
West North Central	16.2	0.1	2.8	2.3	14.0	8.5
South Atlantic	34.1	8.4	18.7	42.5	24.5	26.9
East South Central	15.9	8.1	0.3	26.8	10.0	11.9
West South Central	18.5	39.5	0.0	0.0	14.9	13.6
Mountain	1.4	2.7	0.0	6.7	2.5	1.7
Pacific	3.3	33.6	19.8	0.0	12.9	15.1

Use of different types of energy varies widely within the individual regions. Gasoline and diesel fuels substitute for each other. The proportion of diesel fuel used becomes larger from the West North Central and West South Central regions toward the Mountain and Pacific regions, probably reflecting the kinds of equipment bought for extensive types of crop farming. In the Pacific region, diesel fuel accounts for almost three-fifths of the combined gasoline-diesel total. Propane, natural gas, fuel oil, and coal are used for heating. Fuel oil is the most important heating fuel in New England, and natural gas is the major heating fuel in the Pacific region. Propane is the major heating fuel in all other regions. Natural gas is the second most important heating fuel in the Mountain, South Central, and Middle Atlantic regions. Coal is the third most important heating fuel used in the Middle Atlantic, Mountain, and East South Central regions. Fuel oil is the third most important heating fuel in the Pacific region (table 4).

Some of the emphasis on the use of certain fuels within regions is related to either proximity of local supplies or lower prices, or both. For instance, coal is being used in some of the Middle Atlantic, Southern, Midwestern, and Mountain States. Natural gas usage tends to be highest in and adjacent to the Gulf and Western States. There is, however, some offpipeline use in other States and some instances of dependency on natural gas, such as in the Long Island duck industry. The heavy dependence on fuel oil in New England poultry and egg production reflects the general situation prevailing in that region which has no developed local output of fossil fuels. There are a few other areas where fuel oil use depends on local preferences or the particular practice in certain industries. The heavy dependence of poultry and egg production on propane in most regions, and on natural gas in others, also poses potential problems in the long run.

Table 4--Percentage of motor fuels and heating fuels used in poultry production by regions, 1974

Region	Motor fuels 1/		Heating fuels 1/			
	Gasoline	Diesel	Propane	Natural gas	Fuel oil	Coal
	Percent					
New England	100.0	0.0	11.9	0.0	88.1	0.0
Middle Atlantic	97.7	2.3	56.6	27.0	6.5	10.0
East North Central	94.9	5.1	87.2	5.0	4.6	3.2
West North Central	88.1	11.9	98.1	0.2	1.1	0.6
South Atlantic	98.6	1.4	86.5	5.9	3.2	4.3
East South Central	98.3	1.7	82.7	11.6	0.1	5.6
West South Central	78.4	21.6	63.0	37.0	0.0	0.0
Mountain	63.0	37.0	58.4	30.5	0.0	11.1
Pacific	42.0	58.0	23.8	66.5	9.7	0.0
United States	85.1	14.9	72.3	19.9	4.9	2.9

1/ Regional percentages of motor fuels and heating fuels each add to 100 percent except for rounding errors.

Seasonality of Use

Aggregate U.S. requirements in particular months for various types of energy are influenced by the relative proportions of various energy sources used by regions. The range in seasonal requirements for each type of energy varies from region to region, and is affected by climatic conditions, housing types, management practices, and levels of efficiency in energy use.

Average monthly requirements for energy in poultry and egg production are 118 million kWh's of electricity, 2.6 million gallons of gasoline and diesel fuel, 16.2 million gallons of propane, 4.1 million therms of natural gas, 736,000 gallons of fuel oil, and 2,700 tons of coal (table 5). But the monthly requirements vary widely from these levels. Requirements for electricity during the peak month of July exceed 164 million kWh's, nearly twice the amount required in November, the low month. Gasoline and diesel fuel needs of 3.7 million gallons in May are nearly twice the December low. Propane requirements of 33.6 million gallons in January are almost 11 times as large as the needs in August. In January, almost 9 million therms of natural gas are required, nine times the August level. Coal needs of over 5,600 tons in January are about nine times July needs. In January, 1.4 million gallons of fuel oil are needed, more than five times the July requirements.

Table 5--Monthly energy needs in poultry production for United States by type, 1974

Month	Propane	Natural gas	Fuel oil	Coal	Gasoline and diesel	Electricity
	Million gallons	Million therms	Million gallons	1,000 tons	Million gallons	Million kWh's
January	33.6	9.0	1.4	5.6	2.1	110.3
February	28.6	7.2	1.1	4.7	2.9	103.9
March	29.2	7.1	1.1	4.8	2.8	106.6
April	18.9	4.7	0.8	3.1	3.4	103.2
May	12.9	3.3	0.6	2.0	3.7	119.2
June	6.5	1.9	0.3	1.0	3.2	135.2
July	3.4	1.2	0.2	0.6	2.6	164.2
August	3.1	1.0	0.3	0.6	2.1	159.6
September	4.9	1.3	0.3	0.9	2.3	112.4
October	9.7	2.4	0.6	1.7	2.6	99.1
November	17.2	3.8	0.8	3.0	2.5	98.7
December	26.9	6.6	1.2	4.7	2.1	103.4
Total	194.9	49.3	8.8	32.7	31.5	1,415.9
Average	16.2	4.1	0.7	2.7	2.6	118.0

The data in table 6 illustrate both the levels of energy use and the seasonal changes under selected conditions. The comparisons are paired by commodity and energy type, using different States and conditions. Since there are interrelationships between heating fuel use and electricity use as housing types and growing practices change, some examples for broilers and turkeys include both sources of energy.

Climatic conditions alone would indicate a substantial increase in propane use for broiler brooding in a Northern compared to a Southern State, if housing types remained constant. However, the extent of this increase in the example shown is restricted by the shift from a low to a high percentage of environmentally controlled (tighter and better insulated) housing. Also, a shift from more conventional toward environmentally controlled housing would eventually double electricity use because fan ventilation requirements would increase considerably. But in the example, the rate of increase is less in the North than in the South because the cooler northern climate requires less electricity for ventilation and cooling. The effect of climate on propane and electricity use is illustrated by the flatter seasonal patterns in the North. In the South, higher summer temperatures result in very low propane needs and much higher rates of electricity use.

The examples shown for the use of propane and electricity as sources of energy in turkey production illustrate not only climatic effects, but also the

Table 6--Monthly use of energy in different regions, by type of poultry and poultry housing conditions, 1974

Example	Energy type	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual use 1/
		Monthly rate of use as percent of average monthly rate												per 1,000 birds
		Percent												
Broilers:														
Northern State, semi and environmentally controlled housing	Propane	204.0	178.0	153.7	95.5	55.4	30.6	19.5	24.3	42.2	77.0	130.3	189.6	56.4
	Electricity	99.0	94.0	90.0	88.0	91.0	101.0	118.0	122.0	104.0	99.0	96.0	98.0	226
Southern State, 10% environmentally controlled housing	Propane	219.3	180.5	151.7	81.5	52.3	19.9	8.5	12.5	35.3	80.1	146.9	211.3	44.0
	Electricity	92.0	83.0	78.0	78.0	90.0	110.0	140.0	135.0	115.0	98.0	90.0	91.0	45
Turkeys:														
Midwestern State, 70% Confinement rearing, fair housing	Propane	192.1	156.9	124.9	99.4	76.9	56.4	37.3	37.7	52.0	82.4	121.1	162.9	700
	Electricity	96.4	96.4	84.3	78.3	78.3	102.4	144.6	144.6	96.4	90.4	93.4	96.4	599
West Coast State, 5% Confinement rearing	Propane	174.9	140.7	114.1	83.6	60.8	55.1	60.8	72.2	83.6	98.9	117.9	138.8	264
	Electricity	93.0	93.0	81.0	74.0	74.0	110.0	165.0	160.0	100.0	80.0	85.0	85.0	442
Hens:														
Northern State closed housing, high mechanization	Electricity	88.0	87.0	85.0	84.0	94.0	105.0	135.0	140.0	104.0	94.0	92.0	90.0	3,829
Southern State largely open housing, medium mechanization	Electricity	83.0	82.0	77.0	75.0	95.0	118.0	160.0	155.0	100.0	86.0	85.0	84.0	2,400
Northern State	Gasoline/ diesel	78.0	75.8	85.0	106.8	107.0	107.8	93.0	93.3	112.0	124.5	124.5	92.5	40.0
Southern State		86.8	84.5	93.7	103.0	103.3	98.8	96.8	97.0	112.5	115.7	115.7	92.5	40.0
Turkeys:														
Northern State, 80% range reared,	Gasoline/ diesel	47.5	49.2	54.1	68.9	104.9	113.1	136.1	134.4	159.0	170.5	103.3	59.0	61.0
20% range reared	Gasoline/ diesel	69.0	71.4	78.6	100.0	114.3	107.1	92.9	90.5	126.2	142.9	121.4	85.7	42.0

1/ Propane, gasoline, and diesel units are in gallons and electricity is in kilowatt-hours.

effect of widely varying percentages of range compared to confinement rearing. In the Midwestern State, propane use is high, reflecting more cold weather brooding, heating to maintain dry litter, and also a low degree of housing insulation. Electricity use is also relatively high because of the need for more ventilation in closed housing. For both types of energy, seasonal patterns are flatter due to the need for more heat and relatively less electricity for cooling during summer months. The West Coast State, where summers are hotter, shows wider seasonal variation in heating fuel and electricity use. Thus, while electricity needs for cooling during summer are high, more open housing, warmer weather, and confinement rearing mean lower annual use of heating fuel and a lower use of electricity for ventilation to maintain dry litter.

The comparison of electricity use on laying hens in a Northern and Southern State illustrates the combined effects of climate, housing types, and degrees of mechanization. Although seasonal variation in electricity use in the Southern State is higher due to summer cooling needs, the annual use is lower. In many months, electricity use for ventilation is lower because of the relatively open housing. In the Northern State, the percentage of environmentally controlled housing is higher, adding to requirements for ventilation. Moreover, in the example, the Northern State had a much higher rate of mechanization, mechanical feeding, egg collecting, and manure removal systems, and more onfarm egg grading and packing.

The total annual use of gasoline and diesel fuel on egg farms is similar for the Northern and Southern State. But the seasonal variation in use is greater in the Northern State, because winter weather limits year-round spreading of manure. In either region, cleaning can occur frequently, even daily, with cage operations, but only between flocks on floor operations.

The example of gasoline and diesel use for turkey production shows the contrast between a higher and lower percentage of range rearing in a Northern State. With more range rearing, more fuel is needed for range feeding and maintenance operations. With less range rearing, there are greater requirements for cleaning and spreading manure and litter. But on an annual basis, this does not offset the higher range feeding and maintenance requirements in the alternative situation.

Functional Uses

The level and seasonality of use of heating fuels, electricity, and motor fuels are greatly affected by the management practices, housing types, and the extent of automation in production operations. Table 7 provides some regional estimates of these factors for turkey, chicken, and egg production. Characteristic practices and conditions often vary widely among States within the same region.

An important source of variation in energy use for turkey production is the relative proportion of output raised in confinement. The opposite effect of this measurement is the proportion of birds which are range reared after the brooding period and as weather permits. Even under confinement rearing,

Table 7--Estimates of major factors affecting energy use, by regions and United States, 1974

Item	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	United States
					Percent					
Turkeys raised in confinement 1/	71.5	89.2	29.5	52.3	60.4	50.0	39.2	22.5	7.8	42.2
Nonbroiler chickens raised in confinement 2/	97.0	91.9	84.0	70.0	97.2	96.6	95.3	92.0	98.4	91.1
Broilers raised, by housing type:										
Open	---	---	---	26.5	44.8	77.6	78.4	---	37.9	57.4
Semienvironmental	0.3	49.3	46.6	24.8	34.7	12.4	11.6	---	32.4	23.2
Environmental	99.7	50.7	53.4	48.7	20.5	10.0	10.0	---	29.7	19.4
Laying hens raised, by housing type:										
Open 3/	3.6	13.7	29.8	47.9	79.7	80.8	83.9	29.3	13.9	48.1
Semienvironmental	74.9	65.4	58.8	29.7	12.6	11.8	8.2	55.1	48.8	35.1
Environmental	21.5	20.9	11.4	22.4	7.7	7.4	7.9	15.6	37.3	16.8
Degree of automation of laying hen units:										
Zero to low 4/	25.1	19.4	55.3	55.9	17.4	19.2	20.6	27.9	4.1	26.2
Medium	44.7	46.7	35.7	29.6	52.1	48.3	55.5	48.1	49.7	45.9
High	30.2	33.9	9.0	14.5	30.5	32.5	23.9	24.0	46.2	27.9
Extent of cage operations on laying hens 5/:										
All birds	48.4	69.0	81.9	83.1	58.4	45.0	54.7	90.4	92.7	69.2
Table egg birds	53.1	70.7	84.4	87.0	71.6	59.7	68.7	92.7	96.4	78.0

1/ Confinement does not always mean fully enclosed floor houses. In some areas of the South it may include restricted outside yards and might be called semi-confinement. 2/ Includes laying flock replacements, plus some meat chickens. 3/ In northern States, would be all small flocks; in southern States, a large proportion would be open-style houses on commercial farms. 4/ Small flocks would account for some of this category. 5/ Based on data from 1971 special census on poultry (45). "All birds" ratios include hens and pullets in both table egg and hatching egg flocks. "Table egg birds" ratios are estimated by assuming all hatching egg birds as floor operations.

however, energy use varies widely among relatively open, closed and uninsulated, and environmentally controlled and heavily insulated houses. Confinement rearing also involves various types of systems, from brooding and growing in the same houses to centralized brooding followed by separate growing houses which may have outside wire platforms or restricted outside pens. About 42 percent of the Nation's turkeys were grown under confinement systems in 1974.

Confinement rearing of replacement chickens, mainly pullets, has grown rapidly over the past decade at the expense of range rearing, which formerly predominated. In 1974, about 91 percent of the nonbroiler chickens, including pullets for laying flock replacements plus some meat chickens, were grown in confinement.

Virtually all broilers are raised in confinement with only a fraction of 1 percent (farm flocks) having access to the ground. A major factor affecting energy use in broiler production, therefore, is the type of housing. While the extent of insulation varies somewhat within particular types of housing, over 57 percent of the broilers produced in 1974 were in relatively open houses, over 19 percent were in environmentally controlled houses, and the remainder were in semienvironmental houses.

Most of the large flocks of laying hens are in confinement operations. Most of the nonconfinement operations are in small farm flocks, which accounted for less than one-eighth of the laying birds in 1974. About 48 percent of the laying birds were in small flocks and open-type housing operations, compared with 35 percent in semienvironmental and almost 17 percent in environmentally controlled housing. Over 26 percent of the birds were in units with zero to a low degree of mechanization. Almost 46 percent were in units with a medium level of mechanization, and the remainder, almost 28 percent, were in units with a high degree of mechanization.

In 1971, over 62 percent of all laying birds (table plus hatching egg flocks) were in cage operations. The proportion of table egg birds in cages was 78 percent in 1971 and is probably higher now.

In 1973, data from four major producing States indicated that 21 percent of the ducks were raised on drylot operations; 23 percent of the units were drylot operations and the remainder were wetlot operations. Proportions of producing units that were drylot operations were well below national average levels in New York, higher in the Midwest, and predominant in California. Close confinement rearing was increasing, partly due to potential water pollution problems. With the notable exception of farm flocks of geese, most other types of miscellaneous poultry, such as game birds, were mainly raised in confinement operations.

Various practices, housing types and conditions, degrees of automation, and production areas affect not only the average and seasonal levels of energy use, but also the proportions of motor fuels and electricity used for various functions. Weighted monthly averages of heating fuel use are often lower than simple averages. This is especially noticeable for production of turkeys and other poultry for which seasonal variation is marked and concentrated in warmer months. Heating fuel used for production of turkeys, nonbroiler chickens, and most other poultry may often be higher per 1,000 birds than for broilers because more space is required per bird.

Heating Fuels

Propane, natural gas, fuel oil, and coal are used mainly for heating purposes, especially brooding during the first few weeks. Use of heat during the summer is minimal (only for a few weeks or at night and on cool days). However, during the winter, heat may be needed almost continuously for up to 6 weeks or more. Some fuel is also used to operate incinerators to destroy dead birds. Incineration is virtually the only use of these fuels on egg-producing flocks. Although some fuel could also be used for manure drying, this was not reflected by sample farms.

Fuel use rates for brooding purposes would, of course, be much lower in warmer regions than in colder regions with the same kinds of housing and management practices. A heating degree day is a good statistical measure of this shift. 3/ But the rates of use in the South are often higher than climatic differences would suggest because housing is more open than in the North. Conversely, proportionately more closed and more heavily insulated housing in many Northern States reduces expected fuel use.

Heating fuel consumption has received less attention than it deserves by many firms and producers. This partly reflects low fuel prices and a preoccupation with larger cost items, such as feed, and reflects the attempt to minimize disease and litter problems by supplying more than ample heat. With natural gas prices particularly low, especially in and adjacent to natural gas-producing States, use of this fuel has often been inefficient.

Heating fuels, plus a minor amount of electricity, may be used in individual brooding units. However, fuel oil and coal are sometimes used for central heating systems. In the past, central systems (hot water) were more commonly used in large brooding operations. These systems are no longer used extensively, except in a few States, although general use may grow in the future.

Table 8 summarizes the rates of usage for various heating fuels and the proportions of birds affected. The range of propane used for broiler production by States represents differences between Southern States with more open housing and Northern States with mostly semienvironmental and some fully environmentally controlled houses. The range of propane used for turkey production reflects similar North to South variation in conditions. The use of heating fuels for incineration, as indicated for laying flocks, is now more prevalent than a few years ago; this trend is related to environmental and zoning considerations.

3/ A heating degree day is equal to 1° F under the standard base of 65° F for 1 day; for example, an average temperature of 58° F for 1 day is equivalent to 7 (65° F minus 58° F) heating degree days.

Table 8--Rate of heating fuel use in poultry production, by percent of birds, U.S. total, and State ranges, 1974

Item 2/	Heating fuels 1/ 4/			
	Propane	Natural gas	Fuel oil	Coal
Broilers:				
Percent of birds 3/	86.9	6.1	5.4	1.7
Units per 1,000 birds, U.S. average	45.3	126.9	38.5	0.36
Units per 1,000 birds, State range	25-72	80-200	32-48	0.28-0.45
Turkeys:				
Percent of birds 3/	79.8	16.2	1.6	2.3
Units per 1,000 birds, U.S. average	379.6	546.9	209.8	1.95
Units per 1,000 birds, State range	168-722	231-822	158-321	1.40-2.60
Hens:				
Percent of birds 3/	79.4	11.5	9.1	---
Units per 1,000 birds, U.S. average	22.5	81.0	20.2	---
Units per 1,000 birds, State range	15-30	72-120	15-30	---
Chickens:				
Percent of birds 3/	82.2	10.2	5.0	2.6
Units per 1,000 birds, U.S. average	100.8	200.8	84.3	0.83
Units per 1,000 birds, State	63-162	98-319	61-130	0.50-2.10
Other poultry:				
Percent of birds 3/	50.6	29.5	14.5	5.4
Units per 1,000 birds, U.S. average	106.2	527.1	52.0	0.97
Units per 1,000 birds, State range	86-132	337-581	34-59	0.59-1.00

1/ Although heating is the major use for these fuels, small amounts of propane, natural gas, and fuel oil are used for incineration on all types of poultry, except hens; major use of these fuels on hens is incineration. Minor amounts of fuels are included for pumping water. Amounts of fuel listed are used for a production cycle (growing a batch of broilers to market age or a 12-month laying cycle for hens. 2/ Turkeys and hens include breeders; chickens mainly include laying flock replacements, but also some nonbroiler meat chickens; and other poultry include ducks, geese, guineas, game birds, etc. 3/ Percent of birds means the total percent of birds affected by heating fuels. Percentages may not add to 100 because of rounding. 4/ Propane and fuel oil units are in gallons; natural gas, therms; coal, tons. State ranges reflect varying importance of various fuels by regions. Rates of use are mostly weighted averages of monthly volumes and rates.

Electricity

Electricity was formerly used mainly for lighting and for water pumping. Although these uses are still important, more electricity is often being used for ventilation, including summer cooling, plus operating various kinds of mechanized equipment.

The water system requires relatively constant amounts of electricity. Increased pumping needs in warmer weather are partially offset by heating needs to protect pumps and pipes in colder weather. Lighting requirements vary with the type of housing. With most types of housing, lighting requirements needed to supplement natural daylight vary seasonally. With "dark" houses of the environmentally controlled type, requirements for lighting are constant and much larger.

Some electricity may be required either for ventilating or cooling, or both, even with relatively open housing. The amount of electrical usage successively increases with semienvironmentally to fully environmentally controlled houses. More fans and automatic controls account for this need. Electricity use also tends to increase in closed houses from cooler to warmer climates. A cooling degree day is a good statistical measure of this shift.4/

Mechanized systems for feeding, collecting eggs, removing manure, and loading out birds are frequently used on larger farms and result in considerable savings of labor. Also, many egg farms have powered equipment for sizing, grading, washing, packing, and cooling eggs. On the average, the extent of mechanization is lowest where the proportion of small flocks is highest and may also be lower in older producing areas. Some electricity would also be required to operate motors on manure-drying equipment where drying was practiced.

Table 9 illustrates the quantities and the division of electricity use by functions. Because these rates are lot or annual averages, they do not show the full range in energy use which occurs with different management systems.

For example, minimal electricity requirements for slightly more than lighting and water for laying flocks might be 1,200 kWh's per 1,000 birds per year. Such a level of use may be likely with smaller units, but even with open-type commercial units in the Midsouth, such a minimal level is easily exceeded with small additions for lighting, some cooling, and some automation. For example, with a rate of 1,900 kWh's per 1,000 layers, 1,300 might be used for lights and water, 300 for automation, and 300 for ventilation. A semienvironmental house with a medium level of automation might require 3,600 kWh's per 1,000 layers, 1,800 of which might be used for lights and water, 400 for automation, and 1,400 for ventilation. In contrast, an environmentally controlled house, highly automated, could require 5,000 kWh's per 1,000 layers, 2,100 of which might be used for lights and water, 1,000 for

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4/ A cooling degree day is equal to 1° F in excess of the standard base of 65° F for 1 day, for example, an average temperature of 68° F for 1 day is equivalent to 3 (68° F minus 65° F) cooling degree days.

Table 9--Rates of electricity use for States, total U.S. average and functions, per 1,000 birds, 1974

Item	Range by States 1/	Total U.S. average 1/	U.S. average by functions 1/				
			Lights	Water	Feeding	Ventilation	Egg collecting, handling
	kWh's per 1,000 birds						
Broilers	138-289	162	63	4	15	80	---
Turkeys 2/	287-564	479	144	25	27	283	---
Hens 2/	1,800-4,000	2,912	1,522	96	287	897	110
Chickens 3/	---	50	20	6	4	20	---
Other poultry 4/	---	30	12	6	2	10	---

1/ Amounts used are for a production cycle, i.e., growing a batch of broilers to market age or a 12-month laying cycle for hens.
2/ Includes breeders.
3/ Mainly laying flock replacements, but includes some nonbroiler meat chickens.
4/ Ducks, geese, game birds, etc.

automation, and 1,900 for ventilation. Ventilation requirements could slightly exceed those listed above in warmer areas and could be slightly less in colder areas. Several farm records indicated electricity requirements exceeding 5,000 kWh's per 1,000 layers with environmentally controlled housing and high degrees of automation, plus egg grading and packing equipment.

The average level of automation for broilers may be relatively consistent for various States. Assuming 15 kWh's per 1,000 broilers for automation, a conventional open house might require 60 kWh's for lights and water and 40 kWh's for ventilation, totaling 115 kWh's. With similar requirements for automation, and 65 kWh's for lights and water, a semienvironmental house might require 70 kWh's for ventilation, or a total of 150 kWh's per 1,000 broilers. Fully environmentally controlled housing with the same level of automation in the Midsouth might require 260 kWh's per 1,000 broilers, including 90 for lights and water and 155 for ventilation. Ventilation requirements could slightly exceed the above in warmer areas and be slightly less in colder areas. Requirements for environmentally controlled houses could also be higher than the annual averages discussed above if production were concentrated during the warmer months.

Automation has not yet been adopted in the production of turkeys to the extent that it has in the production of eggs, and requirements for lighting may be less than that for broiler production. Hence, if it takes 375 kWh's of electricity per 1,000 birds in an area with open housing and no full confinement rearing, about 27 kWh's of this might be used for automation, 135 for lights and water, and 213 for ventilation (much of it for cooling). In contrast, an environmentally controlled house might require 675 kWh's per 1,000 birds, with 27 for mechanization, 216 for lights and water, and 432 for ventilation. Ventilation needs might be lower in colder areas and higher in warmer areas.

Annual electricity requirements for ventilation of turkey houses can be above national annual averages under several alternative conditions. For example, where relatively open housing predominates, as in the South, electricity use increases with rising summer temperatures. As with other types of poultry, fully environmentally controlled housing would require more electricity for ventilation than closed conventional housing, which in turn would require more electricity for ventilation than open housing in areas where all three were feasible. A higher percentage of cold-weather brooding also raises electricity use rates. A combination of cooler climates, more off-season brooding, and much uninsulated housing with large cubic capacity, resulting in high use of heating fuels, would require more electricity for ventilating and litter drying. Because of these factors, electricity use by States sometimes appears to have a bimodal distribution, with some high rates in both warmer and colder States. Fully insulated, environmentally controlled housing has not as yet been widely adopted for turkey production, even to the extent of the low rates for broiler and egg production.

For other poultry production, the degree of automation, artificial lighting, and forced ventilation are not as high in general as for broiler, turkey, and egg production. Electricity usage rates for nonbroiler chickens are not as high as for broilers.

Gasoline and Diesel Fuel

Gasoline and diesel fuel are used for a variety of farm and off-farm activities. There is a small and relatively constant component for general onfarm travel. Additional amounts of fuel are used for hauling birds, eggs, feed, and supplies on and to and from the farm.

Cleaning houses and hauling and spreading of manure and litter consume a substantial share of gasoline and diesel fuel. The timing of cleanout operations varies depending on the nature of production operations. Cleanout of caged layer operations may occur on a fairly regular basis, even daily. Cleanout of floor layer operations occurs annually or periodically with flock liquidation. The use of pits is often accompanied by infrequent cleanout. Litter removal from floor broiler and turkey operations may occur annually, with some topping of caked litter between batches, or alternatively between all batches. In some instances, field spreading occurs frequently if climate permits, but may occur more often in the spring and fall wherever manure is applied to cropland.

The need to clean out houses is reduced wherever range rearing is practiced. More fuel is needed for range management, including fence maintenance, cultivation, and seeding. Some fuel may also be needed to operate waste treatment and water impoundment facilities. Moreover, with range rearing, gasoline and diesel fuel are required for hauling birds to the range, hauling and dispensing feed, moving shelters, and sometimes pumping water.

Table 10 illustrates the rates of gasoline and diesel fuel use among the various activities. The higher levels of usage shown for some types of poultry or States reflect added functions which are included, as well as longer growing periods and fewer batches of birds per year.

Gasoline and diesel fuel use per batch of broilers is at a lower level than for other types of poultry. Since broiler production is almost entirely on contract, pickup of birds and delivery of furnished inputs are performed by the contractor or his agent. Often contractors supply cleaning crews and some equipment and energy inputs. With up to five batches raised per year, use in relation to housing capacity would be correspondingly higher than that shown on a batch basis. For some of the other types of poultry which have fewer batches raised per year, rates of energy use are more likely to be expressed on a housing capacity basis. Broiler estimates also exclude full field spreading of manure and litter to a greater degree than estimates for other types of poultry, since more manure and litter may be picked up for off-farm uses.

Because only 42 percent of the turkeys are raised in confinement, range operations account for an important share of gasoline and diesel fuel use. The same is true for nonbroiler chickens and other poultry. Producer activities in hauling inputs and birds are also more extensive since contract production does not predominate. Also, the manure spreading activities may be extensive since these types of poultry are more likely to be associated with general farming activities and areas. In particular, cleaning and spreading

Table 10--Rates of gasoline and diesel fuel use and relative importance by functions, 1974

Item	Range by States 1/	Total U.S. average 1/	U.S. average by functions 1/		
			Manure handling systems and range maintenance	Range feeding, watering, etc.	Other 5/
Broilers	---	2.0	1.6	---	0.4
Turkeys 2/	36-57	49.2	26.0	13.2	10.0
Hens 2/	---	40.0	25.0	---	15.0
Chickens 3/	20-28	23.1	12.0	3.1	8.0
Other poultry 4/	---	20.0	8.0	6.0	6.0

1/ Amounts used are for a production cycle, i.e., growing a batch of broilers to market age or a 12-month laying cycle for hens.
2/ Includes breeders.
3/ Mainly laying flock replacements, but includes some nonbroiler meat chickens.
4/ Ducks, geese, game birds, etc.
5/ Includes onfarm hauling, and general work, some feed hauling, some bird and egg hauling where performed by producers, delivery of contract-raised replacements to egg producers.

functions may occur more frequently with laying hen cage operations than with other types of poultry operations. Producer activities in hauling inputs and eggs on and off the farm uses substantial amounts of motor fuel. Contract growing of layer replacements may involve using motor fuel for delivering started pullets to egg producers.

ENERGY USE IN MARKETING

The estimated costs of energy used in marketing poultry and egg products in 1974 was about $421 million, or 9 percent of the difference between farm and retail values. 5/ During the midsixties, dollar costs for energy were about half the costs in 1974, and amounted to about 7.5 percent of the difference between farm and retail values.

5/ The data on which energy estimates were based sometimes included utility charges (water, sewer, telephone). These costs, however, were small in relation to expenditures for heating, motor fuels, and electricity. They also contain embodied energy.

While energy prices in 1974 were about double those of the midsixties, total quantitative energy requirements in marketing were about the same for both periods. With the volume of eggs moving through marketing channels about the same as during the midsixties, and with an increase of almost 35 percent in poultry meat volume, energy requirements per unit of volume declined. This reflected both gains in efficiency and changes in marketing channels and product form.

Functional Uses

Of the 1974 energy costs for marketing, 15 percent was for assembly, 26 percent for primary processing and packing, 7 percent for further processing and delivery of further processed products, 16 percent for long-distance transportation, 15 percent for wholesaling, and 22 percent for retailing. Since the midsixties, the shares accounted for by assembly and wholesaling have declined, while the shares for all other functions have increased.

Assembly

Hauling live poultry and eggs from farms to processing and packing plants requires substantial amounts of gasoline and diesel fuel. Energy costs account for about 30 percent of total assembly costs for eggs and broilers and about 40 percent of assembly costs for turkeys. The energy cost share of total assembly costs declined from the midfifties into the early seventies, but has since risen.

As of 1974, energy costs in assembly operations were about 0.43 cent per dozen eggs and almost 0.4 cent per pound of broilers or turkeys (ready-to-cook weight).

Processing

Natural gas, fuel oil, propane, and coal are used for heating purposes. In regions outside natural gas-producing States, there is greater reliance on natural gas for heating by processing plants than by production units. Greater reliance on natural gas increases the vulnerability of such plants to quantitative restrictions. Cost impacts would be particularly evident in places where plants were forced to shift from low-cost natural gas to propane or fuel oil, costing two to four times as much per Btu. In the Northeast, fuel oil is the major energy form used in plant heating. Electricity is used for ventilating and cooling buildings; operating processing lines and equipment; cooling, refrigerating, and freezing products; icemaking; and lighting.

Since the midfifties, energy costs, as a share of total egg-packing costs, have risen from less than 3 percent to more than 5 percent. In broiler processing, the share has risen from 5 to 9 percent; for turkey processing, the share has risen from 12 to 16 percent. The preceding comparisons cover primary processing operations, but 12 percent of egg output and 14 percent of the poultry meat is further processed. Energy costs for egg breaking have amounted to from 2 to 4 percent of total costs, compared with up to 10 percent for egg drying. The proportion of total costs accounted for by energy varies widely with size of plant and different types of further processed poultry products, and generally ranges from 7 to more than 17 percent. 6/

In 1974, energy costs for egg packing were about 0.45 cent per dozen. Energy costs for broiler processing were nearly 0.6 cent per pound of ready-to-cook broiler, compared with about 1 cent per pound for whole, ready-to-cook large turkeys, and as high as 2 cents per pound for whole processed turkeys. Energy costs for further processing poultry products aggregated to almost 1 cent per pound (ready-to-cook weight equivalent). For liquid eggs, energy costs were almost 0.2 cent per dozen (shell egg equivalent), compared with 0.75 cent per dozen for frozen eggs and almost 0.9 cent per dozen for dried eggs. Several months of storage cost allowances were included for frozen and dried eggs.

Comprehensive data on the quantities of different forms of energy used in various processing activities are not yet available. Data from several recent studies show wide variations, which may reflect different plant sizes, rates of use of capacity, different mixes of product forms, and variations in the extent and nature of processing activities.

A study in the Pacific Northwest estimated the following kWh's of electricity used per 1,000 pounds of ready-to-cook poultry processed by years: 1963,85; 1965,93; 1967,99; 1970,107; 1975,117; 1980,126; 1985,137; and 1990,148 (46). In Georgia, it was estimated that 3,320 Btu's were required per head of broiler processed, or probably 4,611 Btu's per head of ready-to-cook broilers (32). In a sample of northeastern broiler processing plants, electricity use ranged from about 120 to 240 kWh's per 1,000 pounds (ready-to-cook weight), plus 5 to 7 therms of natural gas, or up to 10 gallons of fuel oil per 1,000 pounds. This suggests a range from about 4,885 Btu's per head (ready-to-cook weight) for mainly whole birds, up to 7,340 Btu's for more complex processing operations, including some freezing and further processing.

The Georgia study estimated energy requirements in egg-processing plants at 226 Btu's per dozen eggs (32). Electricity use in egg-packing plants in California was about 354 Btu's per dozen, based on 1,575 kWh's of electricity, 32.5 gallons of propane, and 21.5 therms of natural gas per 1,000 cases of eggs (9). Differences in the extent of grading and sizing, packing, cartoning, and plant sizes accounted for these ranges.

Long-Distance Transportation

Gasoline and diesel fuel accounted for most of the energy use. The share of total long-distance transportation costs accounted for by energy has ranged

6/ These comparisons exclude egg or poultry costs and delivery, as well as advertising and selling costs on further processed products.

between one-fourth and one-third during the last two decades, falling from the midfifties to the late sixties and rising since that time. By 1974, the share was 31 to 33 percent. Such energy costs in 1974 per dozen eggs or per pound of ready-to-cook broiler or turkey were well over 0.4 cent per unit.

Wholesaling

Energy in wholesaling use includes heating fuels for maintaining building temperatures; electricity for refrigeration, storage, and lighting; and motor fuels for delivery. Energy now accounts for a smaller share of total wholesaling costs because of the more restricted nature of wholesale distribution. The share of total wholesaling costs represented by energy for eggs decreased from over 20 percent during the midfifties to about 15 percent by 1974; broilers dropped from 18 percent to about 10 percent; and turkeys dropped from 20 percent to 15 percent. Energy costs in 1974 were 0.45 cent per dozen eggs, 0.4 cent per pound of ready-to-cook broiler, and 0.5 cent per pound of ready-to-cook turkey.

Retailing

Energy use in retailing includes heating fuels for temperature maintenance and electricity for refrigeration, storage, and lighting. Energy costs, as a proportion of total retailing costs, tended to remain relatively steady for many years. Recent increases have raised shares from more than 3 percent to about 5 percent on eggs and broilers, and from less than 7 percent to about 13 percent on turkeys. Energy costs in 1974 were 0.5 cent per dozen eggs or per pound of ready-to-cook broiler, and 1.5 cents per pound of ready-to-cook turkey.

All Functions

Freezing and storing costs are included in the processing, wholesaling, and retailing categories. These costs occur in one or more of these functions, depending on marketing channels and products. The aggregates for marketing channels, which exclude further processed products, indicate energy costs for eggs as a share of total costs varied from less than 9 percent in the midfifties to more than 7 percent in the sixties, and are now almost 10 percent. Similar ratios prevailed for broilers. For many years, the share of energy costs for turkeys was relatively stable at about 14 percent, but reached almost 17 percent by 1974. Total costs for energy in these marketing channels in 1974 were about 2.3 cents per dozen eggs or per pound of ready-to-cook broilers, and about 4.8 cents per pound of ready-to-cook turkey.

Efficiency of Use

Upward trends in the efficiency of energy use per unit of volume have been characteristic of poultry and egg marketing in total since the midsixties (table 11). Upward trends in the efficiency of energy use for assembly, long-distance transportation, and wholesaling date back to at least the midfifties.

Table 11--Measurements of energy productivity in marketing in the United States by selected periods (1965-69=100)

Commodity and function	1955-59	1960-64	1965-69	1970-73	1974 1/
Grade A large eggs:					
Assembly	52	70	100	111	101
Packing	118	105	100	102	116
Long-distance transportation	75	91	100	115	130
Wholesaling	75	89	100	166	185
Retailing	113	110	100	116	125
Total 3/	81	92	100	122	132
Broilers (ready-to-cook):					
Assembly	62	96	100	120	120
Processing	111	104	100	107	108
Long-distance transportation	80	91	100	110	119
Wholesaling	77	90	100	161	182
Retailing	113	110	100	117	125
Total 3/	85	98	100	122	128
Turkeys (ready-to-cook):					
Assembly	81	97	100	131	132
Processing 2/	121	110	100	105	94
Long-distance transportation	73	92	100	118	132
Wholesaling	95	96	100	140	187
Retailing 2/	135	122	100	97	92
Total 2/3/	106	106	100	111	109

1/ Preliminary.
2/ The period 1970-74 reflects the effects of changes in product form toward more whole bird processed and cut-up packs. For whole ready-to-cook birds, productivity has probably risen.
3/ All functions.

Source: (3)

Gains in the efficiency of energy use in assembly are related to larger vehicles with heavier loads and decreased mileages traveled per load (increased density of supply areas). In poultry and egg processing, energy productivity declined from the midfifties to the middle and late sixties because of higher energy requirements for more mechanized equipment. More recently, energy productivity in processing standard products has tended to rise due to economies of scale in processing, higher utilization of capacity, and more efficient new equipment. Larger vehicles with heavier gross and net loads, some increases in the shares of output supplied within regions, and some reductions in average travel time have helped increase the efficiency of energy use in long-distance transportation.

The trend toward more direct marketing channels and the decline in traditional wholesaling operations have aided the increase in energy productivity in wholesaling. Despite some tendencies toward wider varieties of product forms in recent years, larger scale operations in retailing have tended to increase the efficiency of energy use.

Some shifts in the relative importance of various product forms have tended to reduce energy use per unit of output for further processing. For example, production of liquid eggs consumes less energy than production of frozen eggs. Also, producing a higher proportion of items such as turkey rolls and roasts, where frozen (or fresh) boned meat is the end result, requires less energy than producing canned or frozen products that require more materials or ingredients.

Seasonality of Use

The monthly use of energy in poultry and egg marketing is usually determined by seasonal patterns in production and processing. However, for these functions--processing, wholesaling, retailing--which need substantial building areas, the effects of seasonal patterns of output are modified by seasonal temperature variations.

The monthly energy requirements for assembly and long-distance transportation are closely related to such variables as farm egg production, egg breaking, poultry slaughter, and further processing of poultry. Some energy needs in processing, wholesaling, and retailing remain relatively constant, although lighting varies somewhat seasonally. Other energy needs, such as for building heat, ventilation, and cooling, are substantially affected by temperature changes. In other instances, in which processing is highly seasonal, energy requirements for operating line equipment can vary significantly on a seasonal basis.

Heating, ventilating, and cooling requirements also vary regionally. The examples in table 12 for selected groups of Southern and Northern States illustrate the relative magnitudes of heating and cooling degree days in the two areas. Deviations from these patterns probably occur in both areas because of the large amounts of heat produced in certain processing operations, tending to reduce the need for supplemental heat in cold weather and increase the need for ventilating and cooling in warmer weather.

Table 12--Factors affecting monthly use of energy in poultry and egg marketing

Month	Chickens		Turkeys		Eggs 1/		South 4/		North 5/	
	Slaughter	Further processed	Slaughter	Further processed	Farm production	Commer-cially broken	Heating degree days 2/	Cooling degree days 3/	Heating degree days 2/	Cooling degree days 3/
	Percent of annual volume						Number			
January	8.7	9.3	4.6	5.8	8.6	6.5	599	5	1281	0
February	7.5	8.3	2.8	4.9	8.0	7.1	451	8	1094	0
March	8.1	9.2	2.8	5.5	8.7	8.2	339	25	945	0
April	8.2	8.9	3.8	5.1	8.5	8.3	105	73	545	0
May	9.1	8.8	5.5	6.1	8.7	9.9	18	212	262	22
June	8.8	7.7	8.3	7.5	8.2	10.1	2	391	67	112
July	8.8	7.2	10.9	9.3	8.3	9.6	0	518	14	233
August	9.0	8.1	13.0	11.8	8.2	9.2	0	495	25	191
September	7.8	8.0	12.0	10.9	7.9	8.2	1	318	144	63
October	9.0	9.2	14.7	13.9	8.2	9.1	85	114	412	7
November	7.5	8.2	13.4	11.3	8.3	7.5	317	13	773	0
December	7.5	7.1	8.2	7.9	8.4	6.3	552	4	1157	0
Total	100.0	100.0	100.0	100.0	100.0	100.0	2469	2176	6719	628

1/ Averages for 1973-74. 2/ Weather Bureau data, 1941-70, average degrees below 65 degrees. 3/ Weather Bureau data, 1941-70, average degrees above 65 degrees. 4/ Combined averages for California, Texas, Arkansas, Georgia, and Florida. 5/ Combined averages for Maine, Minnesota, Delaware-Maryland, Pennsylvania, and Colorado.

Quantities Used

The estimates were based on dollar values for expenditures and on assumptions of the proportions of costs accounted for by electricity, heating fuels, and motor fuels (table 13). It was assumed that most of the expenditures for energy used in assembly and long-distance transportation, plus 40 percent of the wholesaling expenditures, were for motor fuels. Electricity expenditures were assumed to account for two-thirds of the total for primary and further processing, three-fourths for retailing, and one-fourth for wholesaling. The remainders were assumed to represent expenditures on heating fuels. Dollar amounts were divided by estimated costs per unit for various forms of energy. Resulting estimates of energy used in marketing were 6 billion kWh's of electricity, 400 million gallons of propane equivalent, and 400 million gallons of gasoline and diesel fuel, or a total of 112.9 trillion Btu's.

TOTAL ENERGY USE

Energy expenditures for the poultry and egg industry's production and marketing activities in 1974 were almost $550 million (table 13). Less than 25 percent of this amount was used for production, more than 35 percent for assembly and processing, and more than 40 percent for long-distance hauling and distributing functions. In 1965, total dollar expenditures for energy were less than half as large as in 1974. Of the 1965 total, a fifth was used for production, almost a third for assembly and processing, and less than a half for long-distance hauling and distributing functions.

Actual dollar expenditures for energy used for production were less than 2½ times as large in 1974 as in 1965, but were only 16 percent larger on a constant dollar value basis. With 23 percent more head of poultry in 1974, a modest gain in the efficiency of energy use was evidenced. Much of this gain was derived from more efficient use of heating fuels, particularly in broiler production. This gain was more than sufficient to offset larger requirements of electricity, particularly for production of layers and turkeys. Actual dollar expenditures for marketing were twice as large in 1974 as in 1965, but 4 percent smaller on a constant dollar value basis. With product volume larger, particularly for broilers and turkeys, the efficiency of energy use in marketing improved substantially.

Quantities Used

Based on information developed in preceding sections of this report, total 1974 energy requirements for production and marketing activities aggregated to 146.5 trillion Btu's, consisting of 7.4 billion kWh's of electricity, 689 million gallons of heating fuels (propane equivalent), and 432 million gallons of motor fuels.

State estimates of energy use by the poultry and egg industry have been made in several instances (table 14). However, these estimates were not done on a uniform basis and vary widely in methods used for arriving at them and

Table 13--Volumes of output and estimated costs of energy in poultry and egg production and marketing, United States, 1965 and 1974

Item	Unit	1965	1974
		Million	
Farm production volumes:			
Average of layers on farms	Number	301	286
Commercial broilers produced	do.	2,334	2,993
Turkeys produced	do.	105	131
Nonbroiler chickens and other poultry raised	do.	266	295
Costs for energy in production	Dollars	52.6	126.5
Marketing volumes:			
Farm egg production	Cases	182.1	183.0
Less: Eggs used for hatching	do.	11.1	12.3
Less: Eggs used for farm consumption	do.	0.6	0.2
Eggs processed	do.	15.9	21.0
Shell eggs marketed commercially 1/	do.	154.5	149.5
Poultry meat sold ready-to-cook 2/	Pounds	7,271	9,263
Poultry meat further processed	do.	745	1,518
Energy costs in marketing:			
Assembly	Dollars	31.9	65.2
Primary processing	do.	47.7	110.8
Further processing	do.	5.4	18.7
Long-distance transportation 3/	do.	35.1	73.3
Wholesaling, retailing	do.	90.2	153.1
Total	do.	210.3	421.1
Energy, costs, production and marketing	do.	262.9	547.6
Index of energy prices	(1967 = 100)	99	206

1/ Excludes hatching and farm consumption. 2/ Excludes farm consumption. 3/ Includes delivery of further processed.

Table 14--Estimates of energy use for poultry and egg production by selected States and years

Year and State applicable	Propane	Natural gas	Fuel oil	Electricity	Gasoline and diesel
	1,000 gallons	1,000 therms	1,000 gallons	1,000 kWh's	1,000 gallons
1972					
California 1/	4,429	19,232	--	373,045	12,931
1973-74					
Texas 2/	30,000	10,620	--	49,000	14,000
Georgia 3/	11,158	14,020	736	250,513	20,929
1974					
Northern California 4/	23,118	37	34,101	--	13,058
New York 5/	986	--	--	35,860	538

1/ State survey, production, processing, and diesel for feed transport and market transport.
2/ State survey for production and marketing of crops, livestock, and poultry.
3/ Georgia Tech survey, 1974, consumption of the Georgia poultry industry, covering growout, broiler and egg processing, hatcheries, feed mills for electricity, propane, natural gas, and fuel oil. Gasoline and diesel are industry estimates reported in trade press for all stages of production, processing, and marketing.
4/ State survey, all poultry production and processing, including roads, etc.
5/ For layers and replacements only, use in farm production.

functions accounted for by them. Some estimates attempted to account for input supplying activities and others were restricted almost entirely to production. These numbers emphasize the substantial amounts of energy required by the poultry and egg industry. Indepth studies would be necessary to develop adequate and more reliable estimates of energy use by type, area, and season in marketing and input supplying than those that are currently available.

Energy Use in Production Inputs

Hatching and feeding operations are often included in integrated poultry and egg firms. During the sixties, several major research reports examined costs and economies of scale for these operations. Such studies, together with some recent information, can provide some preliminary estimates of energy requirements.

Hatcheries

In 1962, a survey indicated that utility costs in turkey hatcheries were about 0.7 cent per poult, ranging from 0.6 to 1.5 cents, depending on hatchery size (34). In the same study, 1964 costs were developed for model hatcheries producing less than 0.4 million poults to more than 11 million per year. Utility costs ranged from 0.25 to 1.1 cents per poult, depending on hatchery size, rate of use of capacity, and length of operating season. For egg-type chick hatcheries, a 1962 survey showed utitilty costs averaging 1.39 cents per salable pullet chick and ranging from 0.9 to 1.5 cents (33). The study also developed 1964 costs for model hatcheries producing less than 0.2 million to almost 3.8 million pullet chicks per year. Utility costs ranged from 0.28 to 1.18 cents per pullet chick, depending on hatchery size, rate of use of capacity, and length of operating season. During the early sixties, broiler chick hatcheries were much larger and usually operated at near capacity the year round. Consequently, a New Hampshire study in 1964 developed model hatcheries which had utility costs ranging from 0.069 to 0.115 cent per chick produced and averaging 0.086 cent per chick (7). A 1975 Louisiana study estimated utility costs for an above average broiler chick hatchery at more than 0.16 cent per chick, about double the 1964 level (39). Although there have been substantial increases in average sizes of egg-type chick and turkey poult hatcheries since the early sixties, and consequent reductions in utility costs per salable pullet chick or turkey poult, current utility costs per pullet chick or poult in large hatcheries are probably three times or more as large as utility costs per broiler chick due to greater seasonality of output.

Based on the 1964 New Hampshire study, from 19 to 33 kWh's of electricity and 0.8 to 1.7 gallons of fuel oil were required per 1,000 broiler chicks hatched, depending on model hatchery size (7). These estimates in total Btu's ranged from 176,000 to 349,000 per 1,000 chicks hatched. In 1964, electricity costs accounted for 75 to 80 percent of utility costs. A 1974 study in Georgia estimated Btu requirements at 310,000 per 1,000 chicks, or 0.2 cent per chick (32).

Utility costs for distributing broiler chicks by truck from hatcheries to farms were estimated at about 0.15 cent per chick in 1975, nearly double the levels in the 1964 New Hampshire study (39).

Feed

Energy requirements in feed milling vary with mill size, rate of use of capacity, and types of feed produced. Economies of scale exist on utility requirements in feed milling. In a 1968 study, model feed mills ranging in capacity from 80 to 300 tons per operating day showed utility costs of $0.59 to $0.72 per ton when producing all pelleted feeds, compared with $0.18 to $0.34 per ton when producing all mash, and $0.38 to $0.55 when producing half mash and half pelleted feeds (51). Production of all pelleted feeds required 17.5 to 22.5 kWh's of electricity and 1.85 to 2.07 gallons of fuel oil per ton, or 318,000 to 367,000 Btu's per ton. A 1964 study in New Hampshire of model feed mills for supplying mainly pelleted feeds for broiler growing and hatching egg flocks indicated costs ranged from $0.67 to $0.82 per ton of feed

(8). Electrical energy requirements per ton of feed were 18 to 22 kWh's and fuel oil requirements per ton were 1.7 to 2.0 gallons. Btu's required ranged from 300,000 to 355,000 per ton of feed. A 1975 Louisiana study indicated utility costs of $0.85 per ton for a larger than average mill producing a mixture of pelleted and mash feeds for integrated broiler growing and hatching egg flocks (39). A 1974 study in Georgia estimated energy requirements in feed mills at 330,000 Btu's per ton of feed, or $1.15 per ton (32).

In recent years, substantial energy conservation efforts by the feed industry have reduced energy requirements per ton of feed. Recent estimates of in-mill use of energy ranged from 210,000 to 215,000 Btu's per ton of pelleted poultry feed and under 100,000 Btu's per ton of mash.

In addition to feed milling and local distributing, large amounts of energy are embodied in feed ingredients. Energy is embodied during production, drying, primary processing, and long-distance transportation of feed ingredients. One study indicated that the energy requirements for processing and handling per ton of final product were 683,000 Btu's for formula feeds, more than double the feed milling requirement alone (47). The energy used in producing corn, for example, is about 3.7 million Btu's per ton; for soybeans it is almost 3.2 million Btu's per ton. In addition, the processing of 49 percent soybean meal requires almost 1 million Btu's per ton. In contrast, the processing requirements of other feed ingredients range from 20,000 Btu's per ton on grain mill screenings to 10 million or more on alfalfa, several high-grade grain products, and animal protein meals.

With increased density of broiler production and predominant use of large bulk-feed delivery trucks, feed delivery costs are now relatively lower than a decade ago. A 1964 study in New Hampshire estimated delivery costs at $3.73 to $7.40 per ton for small loads and $1.28 to $2.23 for full loads, depending on supply area radius (10). Some recent studies reflecting higher fuel prices have reported delivery costs of feed at $2.00 to $3.50 per ton. Fuel may account for one-third to one-half of these costs. Based on a waybill sampling of corn and soybean meal movements, an average haul of 530 miles was estimated. At 680 Btu's per ton mile, this would require 360,400 Btu's per ton, or 2.57 gallons of diesel fuel per ton of feed moved.

Depending on the type of poultry and regions, most poultry rations probably contain 220,000 to 350,000 Btu's per hundredweight. The compounding of nutritionally balanced rations from many different ingredients is a complex process, and least-cost rations are typically formulated by computer programs. Preliminary results suggest it might be possible to effect a 10- to 20-percent savings in embodied energy in poultry rations, but with current prices of feed ingredients, costs per ton to producers might increase by a smaller to a larger ratio.

Other Measurements of Embodied Energy

A 1974 study of energy consumption in manufacturing developed estimates for selected industries of thousands of Btu's required per 1967 (constant) dollar of value added (table 15) (42). The value-added concept is the value

Table 15--Energy use per dollar of output, United States, by selected manufacturing industry and selected year

(per constant 1967 dollar of shipment)

Industry	1958	1967	1975	1980
	1,000 Btu's 1/			
Prepared Feeds	7.3	10.2	11.2	12.0
Corrugated and solid fiber	11.6	10.0	9.9	9.9
boxes	70.3	37.4	27.0	21.4
Plastic materials and	390.0	371.0	321.0	294.0
resins	8.5	13.9	19.5	22.6
Hydraulic cement	151.6	118.5	155.0	140.0
Ready-mixed concrete	--	3/ 24.9	19.9	16.2
Building paper and board mills				
Pulp, paper, and paperboard mills 2/				

1/ Useful energy basis.
2/ 1,000 Btu's per pound of output.
3/ 1971.

Source: Energy Consumption in Manufacturing. Ballinger Publ. Co., 1974.

of shipments and other receipts minus total costs of materials adjusted for inventory changes. Of particular interest to the poultry and egg industry are the studies of certain 4-digit Standard Industrial Classification (SIC) industries, such as those producing prepared feeds; corrugated and solid fiber boxes; plastic materials and resins; hydraulic cement; ready-mixed concrete; pulp, paper, and paperboard; and building paper and board. These industries are the sources of major inputs such as feed, packaging materials, and building supplies. Some of the primary manufacturing industries are energy intensive, while the secondary using industries are not. But it is also good to keep in mind the long life of building materials and some equipment used by production and marketing establishments. Energy use per unit of output in manufacturing has generally declined and may decline further over the years. The prepared-feed industry is a notable exception, with the increased importance of pelleting and pet foods.

A complete listing of energy embodied in poultry products would also need to include energy used in making the pesticides and specialized equipment used in poultry production and marketing, in crop production, and in commercial salvaging of wastes, which later become poultry feed ingredients. Since pesticides are not used extensively in poultry and egg production, the embodied energy is probably well under one-tenth of 1 percent of the direct energy used annually in production. Embodied energy in making specialized machinery acquired each year is probably only 3 to 4 percent as large as the direct energy used annually in poultry production and marketing.

On the other hand, the amount of embodied energy in raw feed ingredients prior to transportation and milling is very large. It may be three to four times as large as the direct energy used in poultry production, though not as large as the total direct energy used in production and marketing. Some analysts may be tempted to derive adverse conclusions about the high energy costs of poultry production from the embodied energy in feed ingredients. However, it is important to keep in mind the nutritional differences between animal protein and crops, the offsetting energy costs in disposing of byproducts and waste products without creating pollution problems (were they not fed), and the differences between the quality of items fed and those consumed by people.

ENERGY CONSERVATION IN PRODUCTION

In the short run, achieving energy savings is a matter of attention to details and some modifications of existing practices. These approaches require zero to moderate expenditures to gain dollar savings. Good energy-use records will facilitate both the identification of items where current energy use exceeds average standards of performance and the documentation of postadjustment savings. If energy shortages develop, conservation practices may take on an added dimension--avoiding cutbacks in volume or performance by stretching available energy supplies.

Where energy costs are an integral part of contract payments, or where energy is furnished by the contractor, present records may specifically identify energy use. Frequently, however, energy costs may be obscured in farm records, and little attention may be paid to quantities used. Often farm electric meters and heating fuel tanks not only include energy used in poultry production, but also include energy used for household purposes. Records for use of motor fuels may include family travel as well as other farming and business purposes. Separate metering is one possibility for better identification of energy used in poultry production, providing this does not adversely change billing rates. Another approach is to subtract nonpoultry uses from meter readings using more detailed records or estimates of nonpoultry energy use on the farm. Improved energy records are an essential starting point for energy conservation programs.

Energy Performance Variability

Widespread variations exist in the amounts of energy used per 1,000 birds from area to area, among firms in the same area, and among individual farms. Year-to-year variations also occur due to weather and other conditions. The above variations make it difficult to prescribe rigid standards of performance, and suggest that energy conservation requires continuous attention and many adaptations to individual situations. Extension services, poultry associations, and company field personnel can play an important role in developing and encouraging appropriate energy conservation practices.

It is not unusual to find some egg producers in a given State or some contract broiler or turkey producers associated with a particular firm using more than twice as much energy per 1,000 birds as other producers. Variations in energy use may be attributed to differences in housing types, mechanization, elevation, windbreaks, or problems with particular flocks. But much may be due to management and preventable losses. It is also not unusual to find substantial differences in the average rates of energy use among companies operating in the same area. Company records can show more than twice as much heating fuel per 1,000 birds being used by one firm compared with another. Unless such a difference can be explained by sizes of birds being marketed, or if there are greatly distinct policies on housing requirements, the firm using more energy needs to initiate an energy conservation program.

If a company's policies have not changed much and the composition of growers has remained the same, year-to-year variations in energy use of up to one-third can occur due to weather conditions. Variation may also be due to the intensity with which energy conservation measures are pursued. During the winter of 1973/74, for example, prominence of the energy crisis may have resulted in a fuel savings of 20 percent because more attention was given to conserving energy than during the winter of 1974/75, when supplies were more assured.

It is important for meaningful conservation to preserve enough flexibility to recognize legitimate variations in performance and to reduce variations where they can be controlled by instituting changes. Dollar savings for producers can be sizable from instituting energy conservation measures. Quantitatively, energy consumption may be reduced 20 to 50 percent through such measures as using partial house brooding, winterizing side curtains, reducing lighting schedules and light intensity, following proper ventilation practices, using the most efficient fans, using intermittent feeding and lighting, adding insulation, and improving maintenance practices for building and equipment.

Functional Uses

Brooding

Poultry brooding is the most energy intensive function performed in poultry production. The fuel used to heat poultry houses for broilers, layer replacements, or turkey poults accounts for most of the brooding energy used. Fuel consumption per bird can be decreased 20 to 50 percent by adopting existing energy conservation measures and by following good management practices.

Attention to detail in brooding can save energy and money. By following simple rules, such as locating brooders in the center of the house, using solid brooder guards (sheet metal or corrugated paper), clustering brooders in groups of three or four, and following manufacturer's preventive maintenance and adjustment procedures for brooding equipment, a producer can save energy.

Partial house brooding, using a plastic curtain to partition a poultry house and brooding chicks during the first 3 weeks in only part of the house, can save as much as 25 percent of the energy used in brooding. Covering the side curtains with plastic during the winter can save 10 to 15 percent. Energy can also be saved by shutting off brooder pilot lights on some of the brooders as the birds grow older and require less supplemental heat.

Lighting

Lighting of poultry houses is another operation in which energy can be saved. Electricity can be saved by reducing hours of light per day, adding reflectors to maximize use of light produced, using flourescent or mercury lamp lighting, where feasible, instead of incandescent bulbs, improving light location patterns, decreasing light intensity, and increasing use of sunlight.

Adoption of intermittent lighting schedules for broilers, layers, and turkeys can save energy. An example of such a schedule for layers is 8 hours of light, 10 hours of dark, 2 hours of light, and 4 hours of dark. This schedule can save 25 percent of lighting energy, compared with the traditional 14 hours of light and 10 hours of dark schedule. However, adoption of such schedules should only be considered when starting a new flock due to adverse physiological effects on birds accustomed to another lighting schedule.

Adoption of intermittent lighting for broilers, such as 15 minutes of light and 45 minutes of dark relative to 24 hours of light, can save 75 percent of the lighting energy. However, in order to exclude all natural light, such lighting schedules require environmentally controlled housing. Thus, energy savings from lighting would be partially offset by increased energy use in ventilation.

Reducing light intensity can cut electricity use by 25 to 50 percent. Cleaning light bulbs and adding reflectors can reduce light energy use by 25 percent or more through reduction in the size of the bulb required to provide a given level of light intensity. These and other measures, such as use of flourescent lighting, where feasible, can save considerable electrical energy.

Ventilating

The potential savings of energy through improved ventilation and equipment use is very difficult to measure. The side-curtain poultry house may be entirely ventilated without the use of fans; however, the inefficiency of this system in midwinter, due to heat loss, and in midsummer, due to excessive heat, encouraged the development of environmentally controlled housing. This change increases the amount of air which must be moved by fans.

Energy use can be reduced by installing and properly maintaining the most efficient ventilation equipment. An indicator of fan efficiency is cubic feet per minute per watt. However, the efficiency of the ventilation system also depends on the total system design, as the system must provide an even distribution of fresh air while removing moisture, dust, and gases.

Energy savings may also be attained by reducing the ventilation rates. Many poultry houses are overventilated. Local Extension Service engineers should be able to help determine what ventilation schedules are needed.

Producers having poultry houses with an enclosed attic area may be able to save energy during the winter by drawing the incoming air from the attic, since the attic air is as much as 10° to 15°F warmer than the outside air.

Feeding, Watering, and Housing

Although energy used directly in feeding and watering poultry is relatively small, energy savings can still be attained by reducing the number of feeding cycles on mechanical feeders and by properly adjusting and maintaining feeders and waterers. Water spillage not only requires more energy to handle the additional water, but also requires additional heat and ventilation to evaporate the spilled water and remove it from the house.

Longrun energy saving considerations are very important when designing new poultry housing or modifying existing housing. Houses should be designed to provide maximum comfort for the poultry and convenience for the operator at the lowest possible investment and operation cost. Each building should be designed for a specific use in a particular environment. Insulation and systems for heating, ventilating, lighting, feeding, watering, and removing waste should be designed with the realization that higher energy costs and future energy shortages may call for considerable reductions in energy use.

Considerable energy savings are also available from efficient use of existing poultry housing through good management and through modifications, such as installation of additional insulation. Good building maintenance can result in considerable savings. Periodic checks for holes in side curtains, air leakages around doors and windows, dampness or shifting of insulation, and leaks in walls and ceilings can result in reduced energy use.

Selecting the most efficient construction or insulation materials can also save energy and dollars. The insulating capabilities of the various insulation and construction materials vary widely. The type and quantity of insulation preferable in poultry housing vary by region and by type of poultry. Local agricultural engineers are available to assist individuals in determining the correct type and quantity of insulation.

Installation of insulation in existing poultry houses is expensive. However, at current prices the fuel savings attained from insulating a poultry house ceiling can be expected to exceed the cost plus interest over a 10-year period. The savings in fuel use per 1,000 birds in a properly insulated poultry house can be 50 percent or more, compared with fuel use in an uninsulated poultry house. With fuel prices still rising and supplies diminishing, the benefits, economic and otherwise, should increase over time and allow insulation to pay for itself in as few as 5 years.

Many of the comments made in a recent study of energy consumption in selected manufacturing industries apply to energy conservation in poultry and egg marketing (42). In the manufacturing sector energy use per unit of product declined at an annual rate of 1.6 percent from 1954 to 1967. The decline was a result of manufacturers' substituting capital embodying new technology, shifting toward less energy-intensive industries, and realizing economies of scale. Gains in the efficiency of energy use in poultry and egg processing came later.

The substitution of capital for energy can be classified into two categories: housekeeping additions and additions related to changes in the production processes. The first category is mainly directed toward preventing energy waste and can be introduced more quickly. Such improved management practices can result in substantial energy savings in the short run, but often do not have the potential for long-term energy savings that capital substitution does. Increased use of Btu accounting in manufacturing permits the detection of problem areas where energy use can be reduced. Some additions of capital may be involved and, in fact, is the likely approach for recently constructed plants. Older plants can be replaced with new plants designed with energy saving in mind.

Possible energy savings in manufacturing industries from shortrun conservation measures have been estimated at 10 to 15 percent, compared with 35 to 40 percent with major revisions in plants and facilities. For example, instituting a daily system of energy reports by departments could increase awareness and reduce energy use 15 percent. Adjusting combustion equipment and controlling ventilation could result in a 10-percent decline in energy use (1). Such a level of savings may also be obtained in poultry and egg processing. Some ways to save energy in the short run, based on listings of alternatives, are optimum insulating of buildings, ovens, and refrigeration equipment; optimum lighting arrangements with adequate but not excessive light intensity; more frequent and regular maintenance of heating and air-conditioning systems; more efficient heating, air-conditioning, and operating equipment; and improved building and operating equipment maintenance. Other energy-saving recommendations include using less electric heating and more fossil fuel for heating office buildings, installing central heating plants for groups of buildings, instituting internal energy management programs, loading and unloading trucks inside buildings with closed doors, decreasing use of packaging materials, and devising systems to use waste heat (1, 22).

During the late fifties and early sixties, many studies were concerned with increasing the efficiency of assembly operations for poultry and eggs and delivering feed. Increased density of supply areas, as well as reorganization of routes to minimize mileage, was directed toward minimizing labor and truck costs, and generally resulted in coincidental energy savings. Assembly and delivery operations should probably be reexamined, specifically from the standpoint of energy conservation.

Energy audits have been conducted on various poultry and meatpacking operations and bakeries. Energy and cost savings were estimated at 11.6

percent annually, or $148,810, with a $487,985 investment in equipment used per meatpacking firm, and 15 percent, or $91,015, with a $95,225 investment per baking firm (15, 32). Estimates of various conservation efforts are presented below.

Heat from the condensing side of refrigeration compressors could be used for space or water heating, reducing energy consumption in poultry processing plants. Ammonia, commonly used in large refrigeration systems, typically reaches temperatures of 250^{o} to 285^{o} F at compressor discharge. This could be effectively used in heating hot water to 150^{o} F by use of a heat exchanger. A 200-ton refrigeration unit could preheat 650 to 900 gallons of hot water per hour which would be enough scald water for 3,600 broilers. This could save up to $10,000 annually and reduce fan capacity and water needed in the evaporative condenser. Many processing plants have refrigeration unit capacities of 1,000 tons which would supply hot water for 10,000 broilers per hour, plus additional water which could later be used for building and equipment cleanup. Scalded water is discharged at about 125^{o} F. If this could be utilized by a heat exchanger to preheat incoming water from about 60^{o} to 90^{o} F, additional energy could be saved.

Another energy-saving possibility is insulation of hot and cold water pipes. New metal clad insulation would eliminate the deterioration problem associated with high-pressure steam cleaning of insulated pipes after each work shift. An energy audit conducted on meatpacking plants indicated that up to $8,000 could be saved annually with a $17,000 investment.

Additional energy savings could be realized if refrigeration compressors used outside air rather than the warmer room temperature air. Using a steam turbine drive for refrigeration compressors instead of electricity has resulted in savings of up to $40,000 annually for a midwest meatpacking firm. Mechanical power was estimated at about half the cost of electrical power whenever exhaust heat was applied to process uses.

Fluorescent lighting uses about two-thirds less energy than incandescent lighting uses for the same output, and also requires less frequent replacement of bulbs. Estimates of savings for one plant were $500 annually with an initial expenditure of $1,800. Installing photoelectric cells on all floodlights to activate them only when necessary was estimated to save $600 annually at a cost of about $250.

Use of a solenoid valve to control the flow of cooling water to an air compressor was estimated to reduce water cost by $75 annually; installation cost was $150. This would also reduce the plant effluence.

Surface temperature monitors located downstream from steam traps would indicate trap failure. Cost of the monitoring system was estimated at $500 with an annual energy savings of about $1,000.

Demand for electrical energy in peak periods could be reduced by distributing a portion of the processing load into nonpeak hours. Smaller, less costly plant equipment could be used and could result in stabilizing the demand load for air compressors and plant and refrigeration equipment. In the future, variable electric rates may be used with higher rates for the peak demand period of the day and lower rates for nonpeak periods, thus dollar savings could result. However, this would require redistribution of workers into the more expensive evening hours, with the net difference between energy savings and increased labor costs unclear.

Ovens for baking and further processing were also found to be energy-inefficient due either to poor construction or poor utilization. Eliminating downtime for breaks and lunch periods could save an estimated $6,430 per year. Additional annual savings of $20,044 were estimated by eliminating four oven heatups weekly. Energy savings potential exists if oven conveyer space is fully used. Adjustment of burners more frequently was estimated to save considerable energy.

Other suggested ways to improve energy efficiency are to redesign ovens with adequate insulation, to install close-fitting and well-adjusted doors; and to improve burners.

LONG-RANGE ADJUSTMENT POSSIBILITIES

Continuation and worsening of the energy situation could result in major changes in the energy inputs used in producing, processing, and transporting poultry products. These changes could involve alternative energy sources, structural and institutional changes, substantial capital outlays, and closer relationships with other firms. Many potential technical, economic, and legal issues surrounding these problems need to be examined.

Nonconventional Energy Sources

Although various sources of energy exist in forms which can be used with present technology, their use is not economically feasible. These sources, some of which have been known for centuries, have not been developed to their full potential because of relatively expensive initial systems costs and inexpensive fossil fuel resources. Some of these energy sources are solar, methane gas, heat pumps, and windmills.

Solar

Solar energy is an abundant, renewable, and nonpolluting source of energy. However, the diffuse nature of this free resource makes collection and use quite expensive relative to such conventional energies as natural gas, propane, and fuel oil at 1975-76 price levels.

A solar system would typically be comprised of a flat-plate collector; a heat storage unit; hardware consisting of pipes, pumps, and thermostats; plus a system to transfer heat from storage to the area of use. An auxiliary energy source is also required for periods of inclement weather when little or no solar energy is available and stored heat is depleted.

Solar, as a future economically competitive energy source, will depend on factors such as the availability and price of conventional energy resources, the purchase price and installation cost of the unit, the production horizon for the building, and other enterprises for which solar energy could be utilized in nonpeak poultry production periods.

A study to examine the economic feasibility of using solar energy in heating broiler houses concluded that solar energy was more expensive than natural gas and fuel oil throughout an entire 20-year production period (48). The solar system most economically feasible relative to propane use required 13 years before becoming less expensive and provided 41 percent of the total building heating need. A system providing approximately two-thirds of the total heating need would cost about $33,000. To become economically competitive with propane within 3 to 4 years of operation required a reduction of 85 percent from the current initial purchase price. Becoming competitive within 7 to 8 years of operation required a reduction of 70 percent from the current purchase price.

Making solar energy feasible in a shorter time period could be achieved by a combination of circumstances. The two most important factors considered were substantial price increases for conventional energy sources and a drastic reduction in initial solar system purchase prices. The latter could result from new technology or economies from mass production. A change in housing patterns and other uses for solar energy during nonpeak poultry heating periods would spread the large solar fixed cost over a greater volume or over more enterprises.

Solar energy can also be used for cooling purposes by an absorption air-conditioning unit. This system would reduce energy consumption for cooling and spread the fixed solar equipment cost over both the heating and cooling modes. Disadvantages of this method are that a good quality, more expensive collector is required and water temperatures must range from 170° to 200° F, which results in a relatively low collector efficiency.

Other uses for which solar energy might be considered are space or water heating for processing plants, residential structures, or dairy operations, and grain drying. Restrictions or limitations on these uses would be primarily geographic distance from source to use and coordination of heat need among the various enterprises.

Methane Gas

Methane is a gas obtained from waste material by an anaerobic digestion process. The anaerobic process is achieved by placing the waste material in a closed tank which reduces the quantity of material as it gives off the methane gas over time. The waste material used in this process can be comprised of poultry manure, among many other things. Advantages of this process are that the reduced quantity of solid material diminishes the pollution problem and that the methane gas produced can be used as a substitute for other sources of energy. Other advantages are the enhanced fertilizer value of the poultry manure and a reduced fly and rodent problem.

Utilizing this process for poultry might initially seem quite practical since much of the production and all of the processing occur in confinement, thereby reducing problems of collection. This utilization of resources does, however, have its limitations. Like solar, it requires a considerable initial equipment investment. To be used for heating, it requires a system for generation, collection, and safe storage. It would also require a gas flame with an arrester for burning off excess gas.

Methane is an asphyxiating, combustible, and explosive gas. Because of the dangers involved, it requires good equipment repair and close daily supervision. A side product from the generation process is the production of a highly corrosive material, which, when combined with water, forms sulfuric acid.

The methane generation process also requires integration with the total waste disposal system. It can be a batch or continuous flow system, but the operation must be coordinated with initial manure disposal from the building.

Utilizing this process requires specific environmental conditions for maximum gas production potential. These are listed below.

1) A digester temperature of 95° F is needed.

2) Manure to be digested is introduced in the form of a slurry with approximately 10 percent solids. (Because poultry manure is approximately 25 percent solids, water must be introduced thereby actually increasing the volume of waste).

3) Detention time in a generator of 10 to 30 days, depending on temperature control and amount of mixing, is required.

4) Compression is required before using as a fuel.

The anaerobic process, though technologically feasible, has yet to be proven from a practical large-scale application and an economic standpoint (28).

Heat Pumps

Heat pumps may also provide necessary heat for the poultry industry while concurrently reducing energy consumption. Results of a recent study indicated that the normal energy requirements for heating purposes can be reduced significantly by recovering heat from poultry ventilation systems (3). These tests, though conducted on an experimental basis, indicated that given improvements and alterations, heat pumps can be an economically feasible source of heat in the near future.

Another feature of the heat pump is that the cycle can be reversed and used for cooling during warm months. This process could potentially decrease costs of summertime ventilation by reducing the necessary energy input while concurrently maintaining a cooler house environment, thereby increasing feed efficiency and production.

The heat pump could be extensively used in the production and processing of poultry products. Exhaust heat could provide considerable energy for preheating incoming air in the ventilation process. Recovery of heat from waste hot water, machinery, and ventilation heat from processing and packaging plants could provide a considerable heat savings which could be used by the heat pump or some type of heat exchanger.

Windmills

The use of wind may also be an important source of energy in the future. Research is being conducted to examine the technical and economic feasibility of using wind energy to power small electric generators. Such electric power could be used for lighting, operating mechanized equipment, and various other uses (13).

A disadvantage for most geographic areas is the lack of a constant supply of wind for operation, as electrical energy storage is limited and expensive. Like solar and methane gas, another disadvantage is that the high initial system purchase price would probably limit current use of windmills to longrun situations. Additional research on design and geographic placement, plus economies of scale from mass production, should shorten the length of time before windmills become economically feasible.

Heterogeneous Energy Systems

No single energy source previously described is expected to completely replace the current sources of energy. Instead, a heterogeneous system with partial contributions from several energy sources, plus savings from waste heat, is expected.

Those sources which will become technically and economically feasible depend on the magnitude of future uses and new discoveries of supplies of the energy resources currently used. Other important factors in the development of new energy resources are local, national, and international policies, plus the rate of economic depletion of energy resources currently used.

Institutional Barriers and Regulatory Conflicts

A series of regulations and barriers have been built into the U.S. economy with various objectives in mind. Many of these are inefficient with respect to energy use, and reconsideration should perhaps be made in view of the current energy situation.

Modification of existing transportation regulations could enhance energy efficiency and permit more combined-mode arrangements. Established rules currently limit the routes along which cargo can be hauled and eliminate return hauls in many instances. These routes, which are often not the most direct, and return trips without cargo are both sources of energy waste (19). Altering existing regulations would result in energy savings for the poultry industry as well as virtually every other industry.

Greater use of combined-mode transportation arrangements, consisting of rail and piggy-back trailers, barges, and trucks, would decrease energy consumption. Greater use of rail movement over long distances would be more energy efficient than trucks. This would necessitate a fast, regular, and reliable rail service from production and processing areas to consumption centers. The multiple-transportation arrangement would have to be accompanied by a combined-rate structure which would encourage, rather than penalize, users of this service, and also be organized to avoid double handling of the product.

Conflicting regulations among federal agencies result in conflicting goals and policies which use considerable amounts of energy when enforced. Goals exist to increase production, clean up the environment, create more energy independence, and make our country safer. As more agencies attempt to extend their respective programs, additional compromises must be made. Such compromises will be in the form of larger capital outlays for plant and equipment, plus adjustment of other conflicting goals. Industry personnel have indicated that the Government, in attempting to solve problems with multiple regulations, has become a part of the problem (19).

In the poultry processing industry, reuse of hot water for some processing operations could reduce energy consumption. However, implementation of this energy conservation measure is limited because of health regulations. As a substitute for the direct reuse of water, a type of heat exchanger could be used to preheat incoming water while cooling the waste water. This process would reduce both energy consumption and thermal pollution from hot waste water discharge. Another example is pollution abatement from poultry manure disposal and waste water from processing plants. Strict pollution control could utilize large amounts of energy.

Poultry manure contains relatively large amounts of valuable and usable nutrients. Many tests indicate that dried poultry waste is an excellent feedstuff, especially for ruminants which use nitrogen more efficiently than nonruminants. Rations including from 5 to 25 percent of dried poultry waste have shown favorable results when compared to standardized rations. The U.S. Food and Drug Administration (FDA) does not sanction use of this waste product in animal feeds because it may contain drug residues or pathogenic organisms.

Regulations among States differ, resulting in possible energy wastes in some States. The quality of water discharged from processing plants may be required to be much higher in some States relative to others. More uniform regulations among all States could reduce overall energy consumption and not penalize growers or processors located in higher water quality areas.

Answers to these and other questions involve various interest groups and many products; conflicts of interest are inevitable. Another problem exists with the interrelationships among products--especially with environmental issues. Elimination of a problem by one method will normally create problems in several other areas.

Future Energy Conservation

Researchers are continuously examining ways to improve products and decrease energy consumption in all aspects of the poultry industry. Some geographic areas are confronted with pollution problems in disposing of poultry manure. Thermal drying has been used to minimize this problem. Although the method is effective, it uses considerable energy. Reduction in energy required for drying has been examined for caged layers by using a partial in-house drying method (31, 40). This method should reduce net energy consumption, depending on the electrical energy requirements for air circulation.

Use of new types of building materials, such as foam or other materials of high insulating value in the construction of production and processing buildings, could significantly reduce labor construction costs as well as energy use.

Reuse of heat dissipated from ventilation in production and hot water and heat loss from processing operations could result in substantial energy savings. Recovery and use by a heat pump or heat exchanger should result in energy savings, especially when these pumps are used in tighter buildings that restrict warm air movement primarily through the ventilation ducts.

Considerable energy is expended in further processing and transporting poultry products. Further processing of food requires additional energy for cooking and packaging. These convenience foods are gaining a larger share of the total food market. A movement back to more basic foods with less processing would save energy, but these basic foods would probably be resisted by consumers who now enjoy processed convenience food items.

A reexamination of irradiation preservation in large-scale, multiple-commodity operations could be made in view of the current energy situation (43). The large initial equipment expenditure can be best justified in product areas with large volumes and high rates of product deterioration in marketing channels. This will require concentration of processing plants for various types of commodities. Because of high initial cost, public financing should be considered, depending on anticipated benefits of energy conservation, reduced spoilage, and extended shelf life. Longer shelf life allows fewer deliveries consisting of larger quantities to be made, thus saving transportation energy and costs.

Shipment of poultry products in near-vacuum containers could reduce energy consumption and maintain a higher quality product for a longer period. Tests indicated cold-storage life of poultry products can be up to 21 days instead of the average 7 to 14 days. Other advantages include reduction of weight and volume associated with icepacking and potential development of new markets in more distant geographic areas. The major disadvantage of this method of shipment and storage is the high initial cost of the containers.

Changing the present retail marketing system, which involves large conventional retail outlets to a system based on either systematic home deliveries or decentralized retailing facilities (as in residential complexes), could save energy. Consumers expend much energy on individual shopping trips. The alternative system would require a different type of product distribution and consumer acceptance of less browsing and more standardization.

Simplification and standardization of containers is another possible means of reducing energy consumption. Recycling containers also should be examined more closely. Studies indicated energy used in recycling aluminum beverage containers requires only about 5 percent of the energy needed in mining and processing ore for new ones. The increased energy for return transportation and cleaning or remanufacture should be more than offset by decreases in energy used in initial mining, transporting ore, and manufacturing new containers.

Development of energy parks, involving conventional or nuclear generating plants, could involve the production, processing, and waste programs of poultry and egg firms in a totaly integrated system (6). In this system, the heat given off by power generation equipment would be used for space and hot water heating purposes instead of being dissipated into the environment.

Another possibility is the participation of poultry and egg firms in private onsite electricity generation groups. These firms could reduce transmission costs, avoid dependence on large public (regional) networks, and use local wastes and fuel supplies for power generation.

Acceptance and use of these ideas will, in many instances, require cooperation among groups of individuals to justify large equipment installation expense. Many new concepts which promise a reduction in energy use will also require new means of producing, processing, and marketing products. These new concepts will require deviation from the conventional way of doing things and may result in an altered finished product. Therefore, consumer acceptance would be necessary before using these concepts on an industry-wide basis.

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