Energy Consumption and Conservation Opportunities for Arkansas Broiler Production

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Introduction

Arkansas is the nation's third largest chicken producer, with 1.1 billion live birds, or 7.3 billion pounds live weight, produced in 2018 (USDA, 2019). Figure 1 shows the broiler and other meat-type chickens produced in the states including the state of Arkansas in 2017. A large portion of the production costs is on energy consumption for heating, lighting and ventilation (almost 60 percent of a typical contract broiler grower's variable production costs). Heating fuel (natural gas and propane) is needed year-round to provide supplemental heat, while summer cooling and ventilation constitute the majority of the electricity demand.

This factsheet provides a summary of farm and energy use data collected during energy audits for poultry growers in Arkansas from 2011-2013, and identifies potential facility improvements that would reduce energy consumption. The energy consumption in the South Central US represents the baseline data that will be useful in determining energy demand for potential renewable energy applications.

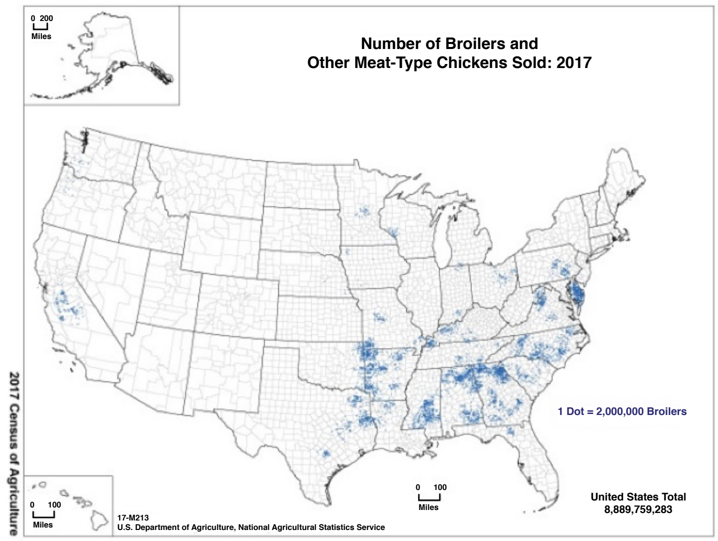


Figure 1. Number of broilers and other meat-type chickens sold in 2017.

A farm energy audit identifies and recommends energy efficient measures to help poultry operations realize substantial energy and monetary savings. Energy audits were conducted on 50 broiler farms (comprised of 252 houses) in Arkansas, following an established standard (ASABE, 2009). Energy audits typically start with site visits to collect data, including construction characteristics of the poultry farm (years, number of houses, house dimensions, size and position of openings, construction materials and insulation, etc.). Site visits also included survey of the installed equipment that consumes energy (the kind of the equipment, the power rating, the number of identical devices and efficiency information) and their location inside the houses. The installed equipment included environmental controllers, heaters, exhaust and cooling fans, lights, feed auger motors, etc.

House tightness was measured in houses when farms were empty at the time of farm visits. Inspection for leaks was visually conducted. A 24-month utility records of consumption and costs for propane or natural gas and electricity were collected from each farm for energy baseline information. Production data collection included target flock age, target weight, number of flocks per year for annual production calculation.

Among the 50 participating farms, 22 farms were located in northern region of Arkansas, with the heating degree days (HDD) of 3,935°Fd (Fayetteville, a base temperature of 65°F) and cooling degree days (CDD) of 1,909°Fd. Twenty-eight farms were located in the southern region with a HDD of 2,431°Fd (Texarkana) and a CDD of 2,349°Fd. Due to the difference in heating demand among geographic regions, the data were grouped into northern and southern regions and analyzed separately.

Farm Characteristics

Table 1 shows the total number of farms, total number of houses, total floor area and the ages of the farms by regions. All houses had tunnel ventilation. The ages of the houses ranged from 4 to 32 years, averaged 15.1 years for the northern region and 16.2 years for southern region. The insulation level of the houses varied greatly, indicated by a wide range of the heat loss coefficients in both northern and southern regions (Table 1). We have also observed damaged doors, faulty fan shutters or ventilation inlets, cracked wall joints above and below the curtains in some older houses. The variation of housing characteristics likely contributed to the wide range of energy consumption presented below (Table 3).

Table 1. Building characteristics and heat loss coefficients of the broiler farms in northern and southern regions in Arkansas.

Region	Number of broiler farms	Number of houses	Total floor area, ft²	Average age of houses (Range), years	Heat loss coefficient[a], Btu/h•°F•ft²
North	22	127	2,274,710	15.1 (9 – 32)	0.20 (0.10 – 0.38)
South	28	125	2,142,680	16.2 (4 – 26)	0.22 (0.06 – 0.37)
Total	50	252	4,417,390		

[a] The heat loss coefficient is the overall heat conductance of the building shell including the effects of framing and doors.

Table 2 shows a summary of the production characteristics pertaining to flock frequency and bird marketing weight by regions. The frequency of flocks correlates to the marketing age and weight of birds (fig. 2); number of flocks per year increased with smaller marketing weights.

Table 2. Production characteristics of 50 broiler farms in northern and southern regions in Arkansas

Region	Number of flocks per year	Chicken Marketing Weight, pound	Chicken Marketing Age, day	Average Annual Production (Birds/farm-year)
North	3.75 – 6.5	3.9 – 8.5	35 - 63	635,000
South	4.8 – 6.5	4.8 – 6.5	42 - 53	432,000

Farm Energy Use Index

Levels of both thermal and electrical energy consumed by farms varied widely (Table 3) when normalized by the productivity level. Arkansas broiler farms located in northern region consumed more thermal energy (0.61 MBtu/per 1000 lb live market weight) than those in southern region (0.37 MBtu/per 1000 lb, Table 3, Figure 3). The amount of normalized electricity consumption was similar between farms in the northern or southern regions.

Figure 2. Market weight vs. market age of broilers raised on the participating farms in Arkansas

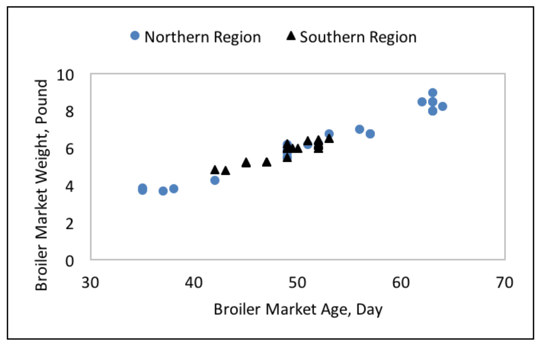
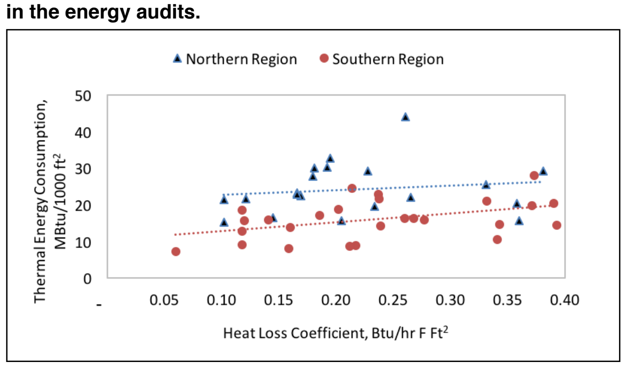


Table 3. Average (and range) of thermal and electrical energy consumed by 50 Arkansas broiler farms on a weight basis or housing footprint basis.

Region	Energy Type	Energy per Weight, MBtu/1000 lb	Energy per Area, MBtu/1000 ft2
North	Thermal Energy	0.61 (0.38 – 1.01)	24.0 (15.3 – 43.9)
	Electrical Energy	0.16 (0.07 – 0.24)	6.3 (3.1 – 11.0)
	Total Energy	0.77 (0.53 – 1.08)	30.2 (20.5 – 47.0)
South	Thermal Energy	0.37 (0.21 – 0.7)	15.1 (7.2 – 28.0)
	Electrical Energy	0.15 (0.21 – 0.77)	6.1 (3.3 – 8.5)
	Total Energy	0.52 (0.36 – 0.88)	21.2 (13.1 – 32.0)
Overall	Thermal Energy	0.49 (0.21 – 1.01)	19.6 (13.6 – 43.9)
	Electrical Energy	0.16 (0.07 – 0.77)	6.2 (3.1 – 11.0)
	Total Energy	0.65 (0.36 – 1.08)	25.7 (13.1 – 47.0)

Figure 3. Normalized thermal energy consumption vs. the building heat loss coefficients of the 50 farms participated in the energy audits.



Winter heat loss by a livestock or poultry production building includes three components: heat loss through walls, ceilings, windows, doors, etc.; heat loss through air exchanges using ventilation fans; and heat loss through air leakage due to unsealed cracks when fans are not in operation. More than half of the houses were built more than 15 years ago, and many were not airtight because of natural deterioration and lack of maintenance. Air exchange rates in winter (called minimum ventilation rates) used by growers vary greatly, causing different levels of air and litter quality (likely contributed to varied broiler performance at market). Hence, higher building heat loss coefficients tend to incur higher supplemental heating fuel consumption (figure 3), but were not the only contributing factor. It is speculated that unsealed cracks along walls and ceilings of the older houses were likely a significant factor for winter heat loss. The wide range of the building heat loss coefficients of the farms (Table 1) indicated that there are great opportunities in making energy improvement of the production houses and increasing overall energy efficiency in the state of Arkansas.

Energy Saving Measures

Energy savings from recommended practices in the energy audit reports were determined by analyzing heating fuel and electricity consumption and the existing building configuration and equipment. Three aspects, such as insulation, lighting and gas heaters, were identified the most to provide the highest energy savings.

Insulation

Proper insulation is crucial in modern broiler production to maintain temperature and humidity level required to raise modern broilers. Broiler houses were constructed as either dropped ceiling or clear-span wood or metal trusses, and with curtain-covered opening or solid sidewalls. About half of the 50 farms had dropped ceiling with insulation above the ceilings. The other half had clear-span trusses with insulation below the roof decks.

Poultry growers can greatly improve energy efficiency and flock performance by insulating the houses to adequate R-values. Table 4 shows the common insulation materials, their frequency of usage and the range of the R-values. With intensive heating required in broiler production, an R-value of 24 is recommended for ceilings. This is much easier to achieve in dropped ceiling houses than the clear-span houses. In dropped-ceiling houses, either complete fiberglass batts or blown-in cellulose is recommended. Sealing air leaks around wall joints, ridge joints, and damaged doors will improve house tightness and reduce unintentional heat loss in the winter months.

Table 4. Insulation materials and their usage in ceiling or walls on the 50 poultry farms and their R-values (hr ft^2 °F/Btu)

Components	Insulation Type	Number of Farms with Each Type	R-value per inch (hr ft^2°F/Btu)	
			Range	Average
Ceiling	Fiber glass or batt	0	2.9 - 3.8	3.2
	Loose-fill fiberglass	0	2.3 - 2.7	2.5
	Loose-fill cellulose	26	3.4 - 3.7	3.5
	Expanded polystyrene board (EPS)	24	3.6 - 4.0	3.8
	Extruded polystyrene board (XPS)	0	4.5 - 5.0	4.8
Wall	Fiber glass or batt	9	2.9 - 3.8	3.2
	Loose-fill cellulose	8	3.4 - 3.7	3.5
	Expanded polystyrene board (EPS)	10	3.6 - 4.0	3.8
	Spray-on polyurethane foam	3	5.6 - 6.3	5.9
	Bubble wrap	7		
	2” plywood with no additional insulation materials	13		1.2

Different options exist when making a decision on the amount of additional insulation based on their economic impact. For example, the amount of two additional depths of two or four inches of blown-in cellulose and the corresponding simple payback periods are shown in Table 5. To retrofit older houses’ sidewalls with curtains, one option is to apply a layer of 1 to 1 ½ inch spray-on closed-cell polyurethane foam insulation from the eave to the floor (Campbell et al., 2006). This procedure avoids additional expense in adding structural wood framing, sheathing, and a vapor barrier to the walls, as is a common practice in enclosing curtained sidewalls (Table 5). A physical protective barrier within bird reach (i.e. the lower two feet of the walls) must be used to protect the exposed foam from birds pecking and darkling beetles’ damages. This can be achieved by either applying a layer of high-density foam (10 pounds/ft) of minimum 1/8” thickness, or interior plywood or OSB sheathing.

Table 5. Examples of energy saving practices, estimated annual energy savings, cost of installation and simple payback periods

Energy Saving Practices	Description	Energy Savings	Estimated Saving, $/year	Estimated Cost, $	Simple Payback, years
Insulate ceiling[a]	Final depth of 4 inches	600 gal propane	$1,200	$1,714	1.4
	Final depth of 6 inches	800 gallon propane	$1,600	$3,428	2.1
Insulate walls	1 inch spray foam to enclose curtained walls	1,130 gallon propane	$2,260	$7,000	3.1
LED lights	LED to replace incandescent	14,700 kWh	$5,400	$4,900	0.9

[a] Blown-in cellulosic insulation in attic of dropped ceiling houses

Assumption: 40' by 500' broiler houses with half-house brooding; currently have 2" loose-fill cellulose in the ceiling; supplemental heat used for brooding of 10 days and whole-house growout for 12 days; Cost of blown-in cellulose to be $0.043/inch of depth added; Estimated energy savings will vary from farm to farm and, because of interactions, are not necessarily cumulative.

Lighting

During the data collection period (2011-2013), the majority of participating farms used 100-watt and 60-watt incandescent bulbs as brooding and growout lights in their poultry houses, respectively. Lighting contributed to a large proportion of electricity consumption, especially in the window-less tunnel-ventilated broilers houses. Compact fluorescent lamps (CFL) were tested to replace incandescent bulbs for their high luminance and high efficiency for several years. However, light emitting diodes (LED) have gained popularity in the past decade due to their reliability, durability (warranty of at least three years) and energy efficiency. The prices of LED light bulbs have dropped significantly and are now widely used in commercial, industrial and residential sectors. Replacing incandescent bulbs with LED light bulbs not only reduces electricity consumption (Table 5), but also provides high performance, long utility life and reduced maintenance costs (for bulb replacement) for poultry operations.

Heating Equipment

Majority of the participating broiler farms (96 percent) used half-house brooding before allowing the birds to full house occupancy for grow-out. Heating equipment varied from pilot-lighted convection jet brooders (Figure 4a, 30,000 Btu/h rating) to radiant heaters (100,000 or 125,000 Btu/h rating). The convective jet brooder and forced air heaters were the most common heating equipment (47 percent of all houses), followed by radiant brooders (43 percent) (figure 4b), and then a smaller percentage (10 percent) of houses used combination of convection and radiant heaters. Propane (82 percent) and natural gas (18 percent) were the primary fuels used for heating the houses in this study.

Radiant heaters allow heat to travel directly to exposed objects, such as from the heater to the floor and birds, without having to heat up the air in between. This is true for all types of radiant heaters, e.g., radiant brooders, radiant tube heaters (figure 4c) and quad-radiant heaters (figure 4d). Since the birds are receiving a portion of their heat from radiant energy, houses can be kept at lower temperatures without affecting bird performance. Radiant heaters can be mounted higher in the house and have a larger radiant zone than the pancake brooders. Radiant brooders can pre-heat the houses faster. Since the house is kept slightly cooler, less heat is lost through the sidewalls and ceilings. With heat more concentrated at the floor, radiant heaters not only can lower gas consumption but also achieve more uniform brooding environment.

Figure 4a. A convection pancake brooder with pilot light

Figure 4b. A round radiant brooder

Figure 4c. A radiant tube heater

Figure 4d. A quad radiant heater

Summary

Production of broiler chickens requires a large amount of energy. This article presented the baseline annual energy consumption in Arkansas broiler houses, and recommended retrofit measures to achieve energy savings. Growers with older, poorly-insulated houses, or outdated lighting and heating equipment will significantly benefit from upgrading the building envelop and adoption of more energy efficient equipment.

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