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EXTENSION

Department of Agricultural & Biological Engineering

Memorandum

To: Chris Ulmer
739 Tabernacle Rd
Salley, SC 29137

From: John P. Chastain
Professor and Extension Engineer
Office: 864-656-4089, e-mail: jchstn@clemson.edu

Date: June 18, 2009

Subject: Energy savings estimates for poultry houses

I have looked into several energy conservation alternatives for your broiler farm since my visit. As you recall, we had originally considered fan upgrades as one of the options. However, as I communicated to you by e-mail and phone, I am not sure we can achieve a substantial pay back by just adding cones to the existing fans. Given that most of your fans are still in good shape there does not appear to be much opportunity for obtaining funding for a ventilation upgrade.

Instead I recommend that you consider making significant upgrades in insulation value and building tightness to save of LP gas use for heating. I also think you have an opportunity to save money by changing to energy efficient lighting.

Therefore the objectives of your USDA-RD grant are to:

1. increase the insulation value and tightness of the walls, and
2. improve the performance and efficiency of the lighting systems.

Wall Upgrade

A previously developed spreadsheet model of the energy balance on a poultry house was used to calculate the benefits of sealing up the sidewalls and adding insulation. The characteristics of the broiler houses on the Ulmer Farm that pertain to heat loss are given in Table 1.

The amount of LP gas used on this farm for four, 42 ft by 500 ft houses was 27,098 gal of LP per year (2008/09). The specific LP gas use was 323 gal LP/ 1000 ft^2 / year.

The basis for the spreadsheet model was the following fundamental equation:

$$\text{q-Sup} = \text{q-Loss} - \text{q-birds.} \quad (1)$$

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Where,

q-Sup = the amount of energy needed to maintain the required indoor temperatures for the birds,
q-Loss = the amount of heat lost from the building, and
q-birds = the amount of heat generated by the birds as the grow.

Table 1. Characteristics of the broiler houses on the Ulmer Farm relevant to the proposed upgrade in the thermal performance of the walls.

Attribute	
House dimensions	42 ft wide x 500 ft long cathedral drop ceiling.
Number of birds/flock	23,300
Side walls	Nominal 4 ft movable curtains with solid walls above and below curtain openings. No insulation
End walls	Solid but not insulated.
Ceiling	Cathedral drop ceiling with about 6 inches fiberglass insulation
Distributed inlets	25 side vents at top of both sidewalls
Cooling Pads	6-inch pads with recirculation, 5 ft tall x 64 ft long, 2 cooling pads per house. Tunnel curtains used during brooding.
Brooding	Half-house brooding with tube heaters in brooding end of building. Spark-ignition box heaters are used in grow-out end of the building.
Doors	Have roll-up doors on front and back. There are 5 walk through doors.
Annual Energy Use for Heating	Based on farm receipts from Farmers Propane it was determined that the 4 houses on this farm used 27,098 gal of LP in a year.

The amount of heat generated by broiler chickens increases as the birds grows. The relationship used in the model is shown in Figure 1.

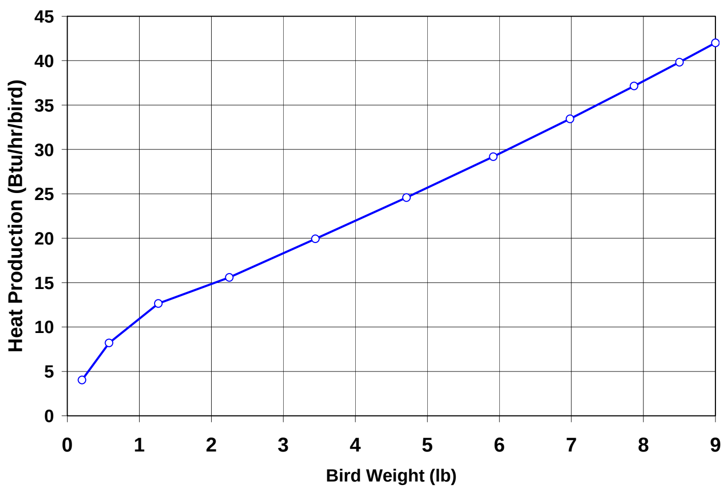

Figure 1. Estimates of heat production from broiler chickens.

The building heat loss was calculated as:

q-Loss = q-ceiling + q-end wall + q-sidewall + q-vent + q-infiltration. (2)

Where,

q-ceiling = heat lost through the ceiling,
q-endwall = heat lost through both endwalls,
q-sidewall = heat lost through both sidewalls,
q-vent = heat lost by the ventilation fans, and

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q-infiltration = heat lost by unintended ventilation cause by building leaks.

An algorithm was developed that allowed estimation of the heat loss from building leakage by estimating the infiltration rate (air-changes per hour) from an interaction with the minimum ventilation fan. The infiltration varied from 1.32 air-changes per hour during warm weather to 2.13 air-changes per hour during cold weather. During hot weather the heat loss due to infiltration was zero.

The heat loss through the walls and ceiling of the structure is a function of the surface areas, total R-values, and temperature differences. The areas and R-values used for the base case are given in Table 2. The temperatures used for five flocks per year are given in Table 3.

Table 2. Insulation R-values and areas used for the existing poultry buildings (each R-value includes standard estimates for convection as recommended by ASHRAE).

Building Component	R-value	Area (ft^2)
Ceiling	20.0	21000
Brooding Half of Building		
End wall	3.0	336
Cooling pad area (tunnel curtains)	1.5	640
Portion of side wall covered by curtain	1.5	1302
Portion of side wall above and below curtain	2.8	1674
Brood curtain	1.5	336
Grow-Out Half of Building		
End wall with fans	2.0	336
Portion of side wall covered by curtain	1.5	1750
Portion of side wall above and below curtain	2.8	2250

Table 3. Average daily temperatures used in analysis by production week.

	House	Winter		Spring		Early Summer		Late Summer		Fall	
Week	T-in (°F)	T-out (°F)	T-attic (°F)	T-out (°F)	T-attic (°F)	T-out (°F)	T-attic (°F)	T-out (°F)	T-attic (°F)	T-out (°F)	T-attic (°F)
1	90	42	52	54	69	74	99	79	104	60	80
2	85.5	42	52	57	72	76	101	77	102	57	77
3	80.5	44	54	59	74	77	102	76	101	54	74
4	75.5	49	59	63	78	79	104	74	99	55	75
5	70	45	55	63	78	79	104	71	96	53	73
6	70	50	60	68	83	79	104	68	93	50	70
7	70	50	60	66	81	82	107	66	91	47	67

The annual LP gas requirement per building estimated using the model and was 6655 gal LP/house/ year or 317 gal LP/1000ft^2 / year. The model estimate agreed within 2% of the farm data (323 gal LP/house/year).

Several insulation and wall sealing alternatives were considered. The most practical options are described below.

Option 1

The curtain openings (3.5 ft tall) would be filled in with ½ inch of extruded polystyrene or polyisocyanate insulation board. The outside of the building would be covered with sidewall curtain material and would be held in place with nailing strips. This would add about R-2.5 to the curtain portion of the sidewall. The main advantage of this option is that it can be added from the outside while chickens are in the building. It will also reduce infiltration by a significant amount.

The projected annual energy savings for option 1 is given in Table 4.

Table 4. Projected annual energy savings for insulation option 1.
Option 1 – add ½ of polystyrene insulation below sidewall curtains.

Reduction In Infiltration Heat Loss (%)	Annual Heating Energy Savings (%)	LP Savings for 4 Houses [1] (gal LP/yr)	Value @ $1.30 / gal ($/yr)
0	13	3522.7	4579.56
25	**24**	**6503.5**	**8454.58**
50	38	10297.2	13386.41

[1] Based on farm usage of 27,098 gal of LP / year.

The model can take into account reductions in infiltration heat loss due to sealing the sidewalls. Table 4 shows results for no reduction in infiltration, 25% reduction in infiltration, and 50% reduction in infiltration. Infiltration heat loss is very difficult to predict since it depends on the number of leaks in the structure, temperature, and wind speed. Given the leaky nature of curtain sidewalls, a 0% reduction is not likely. However, it was included to show the importance of infiltration with regards to LP use. The results for a 25% reduction in infiltration is shown in bold (red) because this level of reduction is most probable.

At the time of the analysis the costs of the retrofit cost was unknown. The cost will vary with the condition of the wall curtains, wire mesh, labor, and materials. Simple payback calculations were performed over a range. The results are shown in Table 5.

Table 5. Simple payback period for option 1 as a function of retrofit cost.
Option 1 – add ½ of polystyrene insulation below sidewall curtains.

Sidewall Insulation Retrofit Cost ($/house)	25% reduction in Infiltration Simple Payback - years
3000	1.34
4000	1.79
5000	2.24
6700	**3.00**
8950	4.00

The critical value is the cost associated with a 3-year payback. Therefore, if the retrofit costs $6,700 per house or less this option is worthy of consideration.

Option 2.

Solid curtain material would be stretched tightly across the outside wall and would be fastened with nailing strips. The inside surface will be supported with the existing wire mesh if it is flat and in good condition. Wire mesh that has been damaged and not flat will need to be replaced. All interior wall surfaces will be receive a 1-inch application of spray-on, soybean-based foam (product name is *AgSeal*). The wire mesh will serve as the form for the foam as it dries to a hard, bird-proof finish. The initial application will be with the 3 lb foam. A final, thin layer of 6 lb material will be sprayed on top of the primary 3-lb layer to provide the peck-proof surface on the bottom 2.5 to 3 ft. A one-inch layer of spray on foam will provide an R-value of 7 to the sidewalls and the end walls. The spray on foam will seal the cracks and crevices in the walls. This treatment should provide the maximum amount of wall sealing.

The projected annual energy savings for option 2 is given in Table 6.

Table 6. Projected annual energy savings for insulation option 2.
Option 2 – add 1-inch of spray on foam (*AgSeal*) to all interior surfaces to seal all cracks.

Reduction In Infiltration Heat Loss (%)	Annual Heating Energy Savings (%)	LP Savings for 4 Houses [1] (gal LP/yr)	Value @ $1.30 / gal ($/yr)
0	24	6503.5	8454.58
25	36	9755.3	12681.86
50	**49**	**13278.0**	**17261.43**

[1] Based on farm usage of 27,098 gal of LP / year.

Option 2 includes adding insulation to the end walls and sidewalls, and will seal up the majority of the leaks in the walls. As a result, a 50% reduction in infiltration seams reasonable. Option 2 has the potential to save twice as much energy as option 1.

The costs for option 2 will range from $8000 to $10,000 per house depending on the condition of the wire mesh and curtains. Simple payback periods were calculated for a variety of retrofit costs to determine the threshold prices for a three and four year payback. The results are given in Table 7.

Table 7. Simple payback period for option 2 as a function of retrofit cost.
Option 2 – add 1-inch of spray on foam (*AgSeal*) to all interior surfaces to seal all cracks.

Sidewall & End Wall Insulation Retrofit Cost ($/house)	25% reduction in Infiltration Simple Payback - years	50% reduction in Infiltration Simple Payback - years
8000	2.52	1.85
9000	2.84	2.09
9830	3.00	2.20
13200	4.10	**3.00**
17250	5.44	4.00

The threshold price per house for a three year payback is $13,200 using a 50% reduction in insulation.

Option 3

One of the concerns associated with spraying *AgSeal* foam directly on to the wire mesh and curtain is possible damage to the exterior curtain and foam. So the third option is to fill in the 3.5 ft tall curtain openings with exterior grade OSB on top of the wire mesh. This should provide the desired protection and an additional R-value of 0.62. It is also believed that a ½ inch application of *AgSeal* may be feasible with this design. This would add R-3.5 to all interior surfaces. The R-value of the curtain portion of the sidewalls would be increased by R-4.12. The exterior curtain material could be nailed over the OSB in the same way as previously described to provide protection from weather.

The projected annual energy savings for option 3 is given in Table 8. The annual LP gas savings for option 3 was only 541.9 gal/year less than for option 2.

Table 8. Projected annual energy savings for insulation option 3.
Option 3 – Fill in curtain areas with ½ inch OSB and add 1/2-inch of spray on foam (*AgSeal*) to all interior surfaces to seal all cracks.

Reduction In Infiltration Heat Loss (%)	Annual Heating Energy Savings (%)	LP Savings for 4 Houses [1] (gal LP/yr)	Value @ $1.30 / gal ($/yr)
0	21	5690.6	7397.75
25	34	9213.3	11977.32
50	47	12736.1	16556.88

[1] Based on farm usage of 27,098 gal of LP / year.

The variation in payback period with retrofit price is given in Table 9. The threshold retrofit price using a three year payback is $12,400.

Table 9. Simple payback period for option 2 as a function of retrofit cost.
Option 3 – Fill in curtain areas with ½ inch OSB and add 1/2-inch of spray on foam (*AgSeal*) to all interior surfaces to seal all cracks.

Sidewall & End Wall Insulation Retrofit Cost ($/house)	25% reduction in Infiltration Simple Payback - years	50% reduction in Infiltration Simple Payback - years
5000	1.67	1.22
7500	2.51	1.83
8950	3.00	2.18
11950	4.00	2.91
12400	4.14	**3.00**

While all three options will provide significant energy savings, options 2 and 3 appear to be the best with energy savings of 47% to 49%.

After bids are secured the final choice can be made and the tables can be used to determine the savings and payback projections.

Lighting System Upgrade

Providing the correct amount of light as chickens grow is a critical factor in management of a profitable broiler farm. The amount of light required ranges from 2 to 2.5 foot-candles (fc) of light during the brooding phase down to 0.3 foot-candle or less when the birds are near market weight. Providing the correct amount of light is needed to maximize weight gain when the birds are young, and to minimize mortality when the birds are heavy.

The majority of the electrical use for lighting occurs during the two-week brooding period. A lighting schedule for broiler chickens is given in Table 10.

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Table 10. Lighting schedule for broiler chickens used by Amick Farms.

Day of Production	Hours of Lighting per Day	Recommended Light Level (fc)
1 to 6	24	2.0 to 2.5
7 to 10	16 (Lights off from 10:00 PM to 6:00 AM)	2.0 to 2.5
11 to 13	16	1.0 to 1.3 (Turn off center lights)
14 to 17	16	0.7 to 0.8 (dim 50%)
18 to 21	16	0.5 to 0.7 (dim by 60%)
22 to 54	20 (Lights off from 10:00 PM to 2:00 AM)	0.2 to 0.4 (dim by 70%)
55	24	0.2 to 0.4

The general equation that can be used for lighting system design for broiler houses is (adapted from Chastain, 1994 and Chastain et al., 1997):

$$IL = LDF\ TLL\ /\ W_A\,. \qquad (3)$$

Where,

IL = average illumination level (fc),
LDF = light depreciation factor = $1.77\ /\ MH$,
MH = mounting height above floor (ft),
TTL = the total lamp lumens (lum), and
W_A = the illuminated floor area (ft^2)

The electric demand for a lighting system is the sum of all of the lamp sizes in Watts divided by 1000, and has the units kW.

The annual energy use is:

$$EU = SD\ t. \qquad (4)$$

Where,

EU = energy use (kWh)
SD = lighting system electric demand (kW), and
t = the total hours the lamps operate per year (h).

The lighting design equations given above were used to develop a poultry lighting design spreadsheet.

The existing lighting provided in the broiler barns is described in Table 11. Only half of the lamps shown are used during half-house brooding.

The illumination levels provided by the existing system and the annual energy use calculations are shown in Table 12.

The results show that the light levels provided by the existing system are far less than recommended by most poultry scientists. The maximum light level provided during the brooding phase is 0.25 fc instead of 2.0 to 2.5 fc. Therefore, the new lighting system needs to provide more light as well as reduce annual energy use per house
Each house on this farm requires about 8976 kWh/year. Therefore, broiler house lighting requires about 35,900 kWh/year. The annual electric use on this poultry farm was 169,453 kWh/year in 2008 based on farm records. Therefore, lighting accounted for about 21% of the electric use on this farm.

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Table 11. Description of the existing lighting system on the Ulmer Farm.
All lamps ate incandescent (Inc.)

	Total Area to Illuminate =20459 ft^2		
	Row 1	Row 2	Row 3
Lamp type	40 W Inc.	40 W Inc.	40 W Inc.
Number	20	20	20
Spacing (ft)	25.0	25.0	25.0
Mounting height (ft)	9.8	11	9.8
spacing / mounting height	2.6	2.3	2.6
Lumens / lamp	480	480	480
LDF	0.181	0.161	0.181
(LDF x TTL)	1734	1545	1734

Table 12. Energy use and illumination levels for the existing lighting system on the Ulmer Farm.
All lamps are incandescent (Inc.).

		Lighting Period (hr/day)	Total Lighting Hours	kW	kWh	Illumination at Bird Level (fc)
Half – House Brooding						
Rows 1, 2 &3	Days 1 - 6	24	144	1.2	172.8	**0.25**
Rows 1, 2 &3	Days 7- 11	16	120	1.2	144.0	**0.25**
Rows 1 & 3	Days 11- 14	16	96	0.8	76.8	**0.17**
		Energy Use for Brooding =			**393.6**	
Grow-Out – Whole House						
Rows 1 & 3	Day 14 - 21	16	192	1.6	307.2	**0.17**
Rows 1 & 3	Day 22- 54	20	660	1.6	1056	**0.17**
Rows 1 & 3	Day 55	24	24	1.6	38.4	**0.17**
		Energy Use for Grow-Out =			**1401.6**	
		Energy Use per Flock =			**1795.2**	
		Energy Use per Year (5 flocks) / house =			**8976**	
Annual Energy Cost per House @ $0.10 / kWh = $897.60 / house / year						

Lighting Option 1

The simplest lighting upgrade is to replace the incandescent lamps with energy efficient lamps with the same or greater light output. Option 1 is to replace all of the 40W incandescent bulbs in the two outside rows over the feed lines with dimmable, 8W cold cathode bulbs (CC), and to replace the bulbs in the center row with 40W compact fluorescent lamps (CFL). The lighting system is described in Table 13.

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Table 13. Option 1 –upgrade existing lamps to energy efficient lighting.

	Total Area to Illuminate =20459 ft^2		
	Row 1	Row 2	Row 3
Lamp type	8 W CC	40W CFL	8 W CC
Number	20	20	20
Spacing (ft)	25.0	25.0	25.0
Mounting height (ft)	9.8	11	9.8
spacing / mounting height	2.6	2.3	2.6
Lumens / lamp	480	3030	480
LDF	0.181	0.161	0.181
(LDF x TTL)	867	4876	867

The illumination levels and energy use, and energy savings projections for option 1 are given in Table 14

This simple upgrade will increase the illumination level during the brooding period to 0.65 fc and will provide a 75% reduction in energy use. The other benefit of this option is that the energy savings will pay for the new energy efficient lamps in 0.71 years.

The main disadvantage is that the light levels will still be well below the levels recommended by poultry scientists.

Table 14. Energy use, and illumination levels for option 1.
Option 1 - upgrade to cold cathode (CC) and compact fluorescent (CFL) bulbs.

		Lighting Period (hr/day)	Total Lighting Hours	kW	kWh	Illumination at Bird Level (fc)
Half – House Brooding						
Rows 1, 2 &3	Days 1 - 6	24	144	0.56	80.64	**0.65**
Rows 1, 2 &3	Days 7- 11	16	120	0.56	67.20	**0.65**
Rows 1 & 3	Days 11- 14	16	96	0.16	15.36	**0.17**
		Energy Use for Brooding =			**163.20**	
Grow-Out – Whole House						
Rows 1 & 3	Day 14 - 21	16	192	0.32	61.44	**0.17**
Rows 1 & 3	Day 22- 54	20	660	0.32	211.2	**0.17**
Rows 1 & 3	Day 55	24	24	0.32	7.68	**0.17**
		Energy Use for Grow-Out =			**280.3**	
		Energy Use per Flock =			**443.5**	
		Energy Use per Year (5 flocks) / house =			**2218**	

Annual Energy Cost per House @ $0.10 / kWh = $221.80 / house / year

Annual Energy Savings Compared to Existing System = 6758 kWh/house/ year (75%)

Value of Energy Savings = $675.80 / house / year

Cost for New Bulbs = $477.80 (8W CC @ $8/ bulb & 40W CFL @ $7.89/bulb)

Simple Payback Period = 0.71 years

Lighting Option 2

The second option to consider is to expand the number of bulbs in each of the three rows from 20 to 50. The system is described in Table 15 and the illumination and energy use projections are in Table 16.

Table 15. Option 2 –add additional lamps to existing circuits to increase illumination level.

	Total Area to Illuminate =20459 ft^2		
	Row 1	Row 2	Row 3
Lamp type	8 W CC	40W CFL	8 W CC
Number	50	50	50
Spacing (ft)	10.0	10.0	10.0
Mounting height (ft)	9.8	11	9.8
spacing / mounting height	1.0	0.9	1.0
Lumens / lamp	480	3030	480
LDF	0.181	0.161	0.181
(LDF x TTL)	4335	24378	4335

Table 16. Energy use, and illumination levels for option 2.
Option 2 - upgrade to cold cathode (CC) and compact fluorescent (CFL) bulbs.

		Lighting Period (hr/day)	Total Lighting Hours	kW	kWh	Illumination at Bird Level (fc)
Half – House Brooding						
Rows 1, 2 &3	Days 1 - 6	24	144	1.4	201.60	**1.6**
Rows 1, 2 &3	Days 7- 11	16	120	1.4	168.00	**1.6**
Rows 1 & 3	Days 11- 14	16	96	0.4	38.40	**0.42**
		Energy Use for Brooding =			408.0	
Grow-Out – Whole House						
Rows 1 & 3	Day 14 - 21	16	192	0.8	153.6	**0.42**
Rows 1 & 3	Day 22- 54	20	660	0.8	528	**0.42**
Rows 1 & 3, dimmed 50%	Day 55	24	24	0.8	19.2	**0.21**
		Energy Use for Grow-Out =			700.8	
		Energy Use per Flock =			**1108.8**	
		Energy Use per Year (5 flocks) / house =			**5544**	
Annual Energy Cost per House @ $0.10 / kWh = $554.40 / house / year						
Annual Energy Savings Compared to Existing System = 3432 kWh/house/ year (38%)						
Value of Energy Savings = $343.20 / house / year						

Option 2 will increase the maximum illumination level from 0.25 to 1.6 fc while saving 38% of the energy needed. However, this system will require a bulb cost of about $1195 per house and new lamp bases in each circuit. Presently, the information is not available to calculate the full cost for this upgrade.

A simple payback calculation using the existing system is not valid since the illumination levels are drastically different. A decision needs to be made concerning the required improvements in lighting system performance.

Lighting Option 3

The third option involves a complete redesign of the lighting system to provide an energy efficient system that will meet all requirements. The third option is shown in Table 17.

Table 17. Option 3 – Use a dimmable and non-dimmable lamp per location over feed lines with a single lamp in the center row.

	Total Area to Illuminate =20459 ft^2				
	Row 1		Row 2	Row 3	
Lamp type	8 W CC	13W CFL	40W CFL	8 W CC	13W CFL
Number	50	50	50	50	50
Spacing (ft)	10.0	10	10.0	10.0	10
Mounting height (ft)	9.8	9.8	11	9.8	9.8
spacing / mounting height	1.0	1.0	0.9	1.0	1.0
Lumens / lamp	480	825	3030	480	825
LDF	0.181	0.181	0.161	0.181	0.181
(LDF x TTL)	4335	7450	24378	4335	7450

The primary difference between option 3 and option 2 is the provision of two different lamps located side by side in the two outside rows located over the feed lines. One is dimmable, the 8W CC lamp, and the other is a 13W CFL. The two outside rows contain to circuits that can be independently controlled. The lighting levels that can be provided by this system and the energy use is given in Table 18.

This lighting system will require 20% less energy to operate while providing the recommended levels of highly uniform light. The expense for this upgrade is much greater that the others. However, if the poultry integrator requires the recommended light levels to be implemented it will be one of the most efficient options.

The incandescent system that will provide similar performance is described in Tables 19 and 20.

If the desired light levels were provided using incandescent bulbs the energy used for lighting on this 4-house broiler would increase by 268%.

Summary

Three options for reducing heating requirements by upgrading the walls have been provided that will provide substantial energy savings. Simple payback calculations were shown for a range of retrofit prices to show the maximum amount that can be spent to provide a 3-year payback. The final task is to select the method to improve wall insulation and tightness and to obtain a bid. The payback can be determined from the tables.

Three energy efficient lighting options have also been provided. As the performance of the lighting system was improved the potential energy savings decreased. A decision needs to be made on how much the lighting system needs to be improved. If the poultry production company requires a full 2.0 to 2.5 fc of light during brooding and the various light levels indicated in Table 10 then option 3 is recommended. If not then option 2 may be the most cost-effective option.

Table 18. Energy use, and illumination levels for option 3.

		Lighting Period (hr/day)	Total Lighting Hours	kW	kWh	Illumination at Bird Level (fc)
Half – House Brooding						
Rows 1, 2 &3	Days 1 - 6	24	144	2.05	295.20	**2.3**
Rows 1, 2 &3	Days 7- 11	16	120	2.05	246.00	**2.3**
Rows 1 & 3	Days 11- 14	16	96	1.05	100.80	**1.2**
		Energy Use for Brooding =			642.0	
Grow-Out – Whole House						
Rows 1 & 3 – only 13W CFL	Day 14 - 21	16	192	1.3	249.6	**0.73**
Rows 1 & 3 – only 8W CC	Day 22- 54	20	660	0.8	528	**0.42**
Rows 1 & 3 – only 8W CC, dimmed 50%	Day 55	24	24	0.8	19.2	**0.21**
		Energy Use for Grow-Out =			796.8	
		Energy Use per Flock =			**1438.8**	
		Energy Use per Year (5 flocks) / house =			**7194**	
Annual Energy Cost per House @ $0.10 / kWh = $719.40 / house / year						
Annual Energy Savings Compared to Existing System = 1782 kWh/house/ year (20%)						
Value of Energy Savings = $178.20 / house / year						

Table 19. Incandescent system to provide similar light levels as option 3.

	Total Area to Illuminate =20459 ft^2				
	Row 1		Row 2	Row 3	
Lamp type	40W Inc.	60W Inc.	150W Inc	40W Inc.	60W Inc.
Number	50	50	50	50	50
Spacing (ft)	10.0	10	10.0	10.0	10
Mounting height (ft)	9.8	9.8	11	9.8	9.8
spacing / mounting height	1.0	1.0	0.9	1.0	1.0
Lumens / lamp	480	875	2700	480	875
LDF	0.181	0.181	0.161	0.181	0.181
(LDF x TTL)	4335	7902	21723	4335	7902

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Table 20. Energy use and illumination levels for incandescent equivalent to option 3.

		Lighting Period (hr/day)	Total Lighting Hours	kW	kWh	Illumination at Bird Level (fc)
Half – House Brooding						
Rows 1, 2 &3	Days 1 - 6	24	144	8.75	1260.0	**2.21**
Rows 1, 2 &3	Days 7- 11	16	120	8.75	1050.0	**2.21**
Rows 1 & 3	Days 11- 14	16	96	5.0	480.0	**1.20**
		Energy Use for Brooding =			2790.0	
Grow-Out – Whole House						
Rows 1 & 3 – only 60W	Day 14 - 21	16	192	6	1152	**0.77**
Rows 1 & 3 – only 40W	Day 22- 54	20	660	4	2640	**0.42**
Rows 1 & 3 – only 40W, dimmed 50%	Day 55	24	24	0.8	19.2	**0.21**
		Energy Use for Grow-Out =			3811.2	
		Energy Use per Flock =			**6601**	
		Energy Use per Year (5 flocks) / house =			**33006**	
Annual Energy Cost per House @ $0.10 / kWh = $3300.60 / house / year						

McAdams Hall, Clemson SC 29634-0312
Phone: 864.656.3250 FAX: 864.656.0338