The University of Georgia

College of Agricultural and Environmental Sciences
Cooperative Extension

Poultry Housing Tips

Hot-Air Alternative Heating System Study - Hot Air Distribution

Volume 21 Number 2 **February, 2009**

Figure 1. Biomass alternative heating system

Over the past decade substantial strides had been made by the broiler industry in reducing overall broiler house fuel usage. With the advent of totally-enclosed houses, circulation fans, radiant heaters, attic inlets, modern controllers, and the increasing popularity of wide houses, propane usage on many farms has been decreased by 50% or more. The problem is that even though fuel usage may have decreased, overall heating costs have increased due to the simple fact that the cost of propane has more than doubled in the past ten years. It is becoming increasingly apparent to many producers that if they want to gain even more control over their heating costs they need to have more flexibility in the type of fuel used to heat their houses, hence the rising interest in alternative heating systems.

Like many of the changes to poultry housing in the past, an alternative heating system will not only require a substantial initial investment by a producer, but producers will also have to spend a fair amount of time learning how to best manage these systems to optimize fuel savings and bird performance. It is similar in many ways to when the concept of tunnel ventilation was first introduced to the poultry industry. Prior to tunnel ventilation, summertime ventilation was fairly simple. When it got hot producers would simply lower their curtains and turn on their circulation fans and fogging nozzles. That was about it. But with tunnel ventilation not only was there a substantial initial cost, but there were more decisions to be made as to how best manage the system to optimize bird performance while at the same time keeping energy usage to a minimum (i.e., How many fans should be operated at what temperature, How to best manage the tunnel curtain opening, etc.) Similarly, a traditional propane heating system is relatively inexpensive to install and fairly simple to manage and maintain. Alternative heating systems in contrast are fairly expensive and are much more involved when it comes to managing house temperature during cold weather. So even though the potential benefit of substantially lower heating costs is very attractive, it is important to realize that these costs will decrease only if the system is properly managed and maintained.

To learn more about the potential fuel savings as well as management issues associated with alternative hot-air heating systems extension engineers and poultry scientists from the University of Georgia as well as a engineer from the Georgia Forestry Commission have been studying a fairly typical hot-air alternative heating system on a commercial broiler farm in Northeast Georgia for the past 18 months. The objectives of the study are to

1) Evaluate the overall cost effectiveness of hot-air alternative heating systems
2) Explore different methods of distributing the hot air produced by these system evenly throughout a 500' long broiler house
3) Quantify the effect these systems have on overall house air and litter quality
4) Document advantages and disadvantages of various types of biomass fuels
5) Explore different methods of controlling hot-air alternative heating systems to produce the most uniform house conditions

The farm where the study is being conducted consists of six fairly typical, 40' X 500' dropped ceiling, tunnel-ventilated houses, approximately seven years of age. Of the six houses on the farm, only four are being used in the study. Two houses were equipped with a hot-air alternative heating system and two are serving as controls. In all four of the houses there are ten radiant brooders on the brooding end (as well as three forced-air furnaces) and two forced-air furnaces on the nonbrooding ends.

All four houses are equipped with a modern poultry house controller (Choretronics II) which is capable of controlling and monitoring all the ventilation/heating equipment in the houses. In addition to the standard six house temperature sensors, each of the four houses is also equipped with humidity, fuel usage, power consumption, and outside temperature sensors. All the controllers on the farm are tied to a central PC for data collection and remote monitoring (via phone modem).

The particular alternative heating systems being studied are manufactured by BioFiber Solutions of Rome, Georgia (Biofibersolutions.com). The heating units (BFS-500A - Figure 1) are capable of delivering approximately 400,000 Btu/hr to a house and can burn either wood pellets or fine ground wood chips (Figure 2). Each unit is connected to an 8.5 cubic yard storage bin with a retractable roof which is capable of storing enough fuel to operate two or more days without refueling (Figure 2). Fuel is automatically fed to the furnace through a conventional three and a half inch feed auger.

Figure 2. Fuel storage bins and fuels types

The furnaces are equipped with a 3,500 cfm, three hp, centrifugal fan which pulls air from the house, then pushes it through a heat exchanger, then returns it to the house after heating it to between 150 and 200^{o}F. The hot air is delivered to a permanently mounted galvanized metal “T-duct” located at the peak of the ceiling via an 18" flexible duct made of curtain material (Figure 3). The 18" T-duct extends out approximately 15' in each direction with a butterfly valve in each end of the “T” to help direct the flow of the hot air within the house (Figures 4 and 6). In one house the hot air is distributed down the length of the house using flexible 18" ducts (connected to the center T-duct) with a series of two-inch diameter holes located down the length of the ducts (Figures 4 and 8). The 18" flexible duct on the brooding curtain side of the T-duct is connected to a second short section of galvanized duct also equipped with a butterfly valve located in the top of the brooding curtain to control the flow of hot air to the nonbrooding end of the house (Figure 6). A series of six 18", 1/15 hp circulation fans located next to the flexible duct further aid in hot-air distribution.

In the second test house, hot air from the heating unit is distributed from the T-duct using a series of eight 16", 1/4 hp, 2,800 cfm variable speed circulation fans (Canarm TF16) positioned along the peak of the ceiling (Figures 5 and 8). The circulation fans were selected based on their ability to drive air well over 60' while producing minimal air movement at floor level. One circulation fan was installed in a hole at the top of the brooding curtain to help preheat the nonbrooding end prior to turning the birds out as well as to help move air to the nonbrooding end once the birds were in full house (Figure 7).

Figure 3. Heating unit air intake and flexible duct delivering hot air to T-duct

Figure 4. T-duct and perforated duct heat delivery system

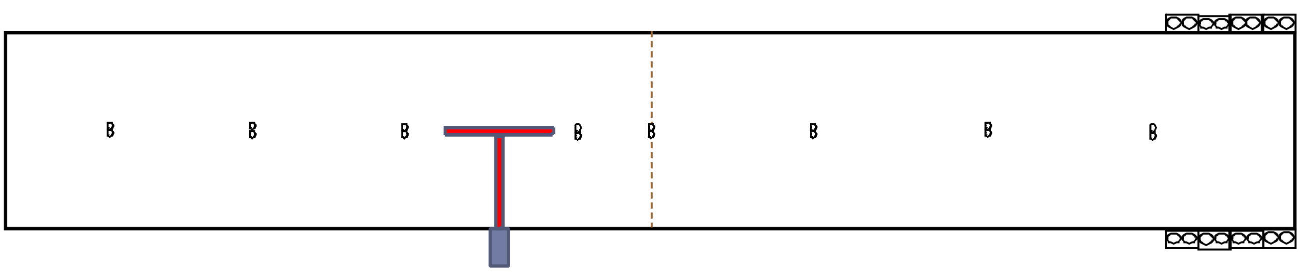

Figure 5. T-duct and circulation fan heat delivery system

Figure 6. T-duct butterfly valve to aid in controlling hot air distribution

Figure 7. Circulation fan located in brooding curtain to deliver hot air to the nonbrooding end of the house

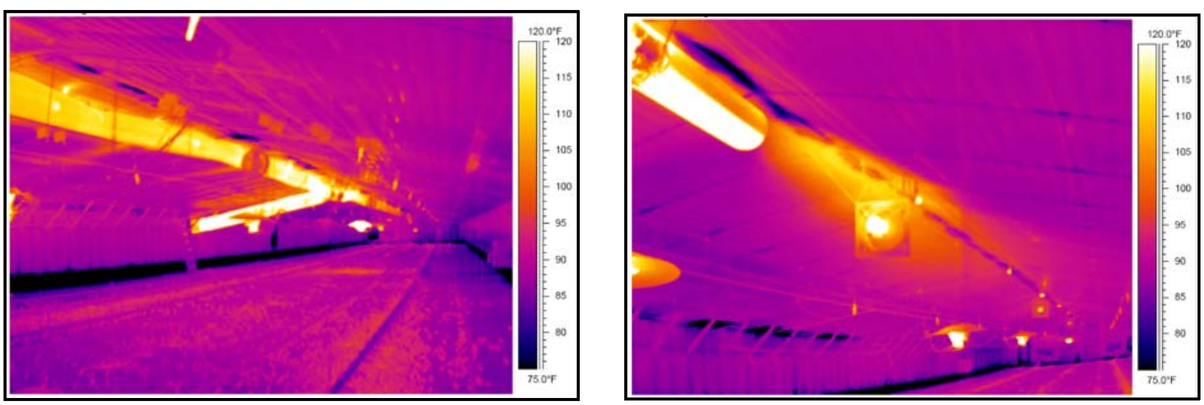

Figure 8. Thermal images of perforated duct and circulation fan heat delivery system in operation.

Basic heating system operation:

1) For the first couple weeks of the flock the alternative heating unit was activated by the environmental controller when average house temperature dropped one degree below the target temperature. Later on in the flock the heating system offset was increased to three degrees. The offset between the desired temperature and the activation of the alternative heating system had to be set fairly close during brooding due to the time required for the unit to begin producing sufficiently hot air. Unlike a propane system (Figure 12), where heat is produced almost instantaneously, it can take several minutes for an alternative heating system to come up to operating temperature. So even though the heat offset was set at one degree, the house temperature could fall as much as three or four degrees before heating unit was producing sufficient heat to arrest the fall in house temperature (Figure 11).

2) The alternative heating systems were set to operate off an average of house temperature. This meant that three temperature sensors were used during half house brooding and six when the birds were in full house.

3) The radiant brooders/furnaces were set to operate if the house temperature in their respective zone fell four degrees below the controller's set temperature. Though it would have been possible to eliminate propane usage it was important from a bird performance standpoint that if for some reason the alternative heating system was not doing an adequate job of heating some area of the house, that the existing propane heating system would act as a backup.

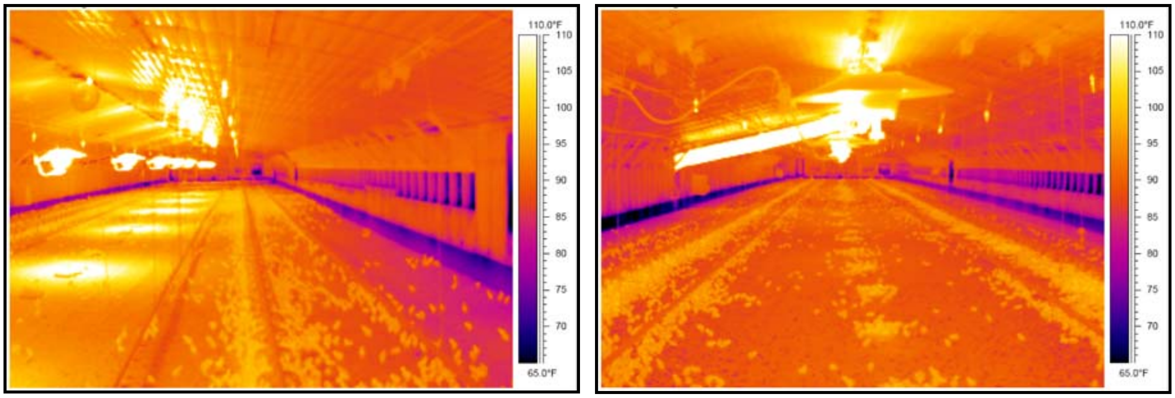

Figure 9. Thermal images of test (right) and control houses (left) when the birds were two days of age.

4) Since the radiant brooders in the houses with the alternative heating systems were essentially only used as back-up heat, this meant the house needed to be operated similar to one using forced air furnaces for brooding. In houses with radiant brooders, floor temperature during brooding typically range from between 85ºF and 115ºF when the air temperature is 90ºF (Figure 9). With a hot-air system, floor temperatures are much more uniform and tend to be a little cooler than air temperatures. For instance, if a controller were set to maintain a temperature of 90ºF, the floor temperature would typically range between 85ºF and 90ºF. To make sure the floor was warm enough in the houses with the alternative heating systems, the controllers were set to maintain a house temperature of 94ºF when the chicks were placed (Figures 9 and 10).

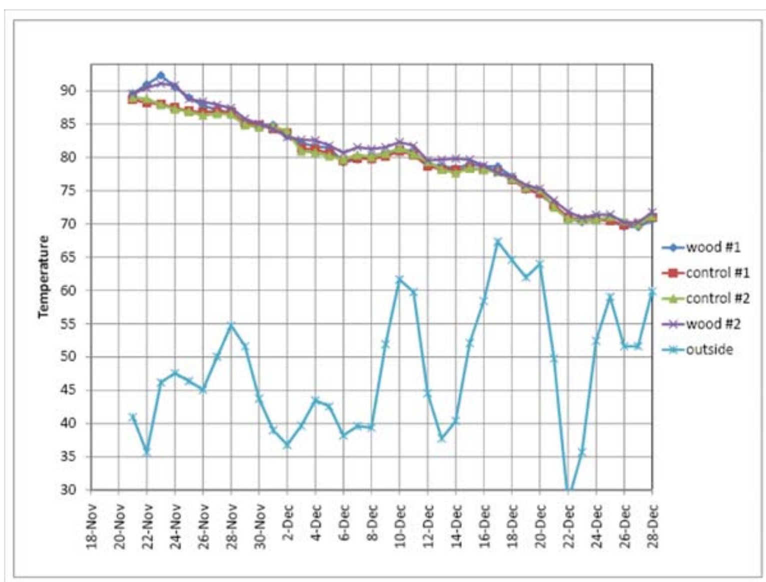

Figure 10. Average daily house and outside air temperature

5) During cold weather when the heating system was operating a significant amount of the time, the blower fan on the unit ran continuously. Though the heating unit controller typically shut off the blower once the temperature of the unit fell below approximately 100ºF, the producer preferred to operate it continuously to avoid scaring the birds every time the flexible tube would inflate; additionally, it appeared to promote house temperature uniformity. In the house utilizing circulation fans for heat distribution, the circulation fans were operated continuously, at full speed, throughout the flock.

6) During brooding, distribution of the hot air within the brooding area was tweaked through the use of two butterfly valves in the T-duct. Two days prior to turning the birds out into the entire house the damper installed in the half house curtain was opened while the butterfly valve in the T-duct directing hot air toward the brooding end wall was

partially closed. In the house utilizing circulation fans, the fan in the brooding curtain was turned on and, like the other house, the butterfly valve in the T-duct directing air toward the brooding end wall was partially closed.

7) A day prior to turning the birds out into full house, the half house curtain was raised and the alternative heating system was programmed to operate off an average of the temperature sensors located throughout the house. The butterfly valve in the T-duct directing air towards the brooding end wall was closed to divert as much heat as possible to the nonbrooding end of the house and the forced air furnaces on the nonbrooding end of the house were turned on as well.

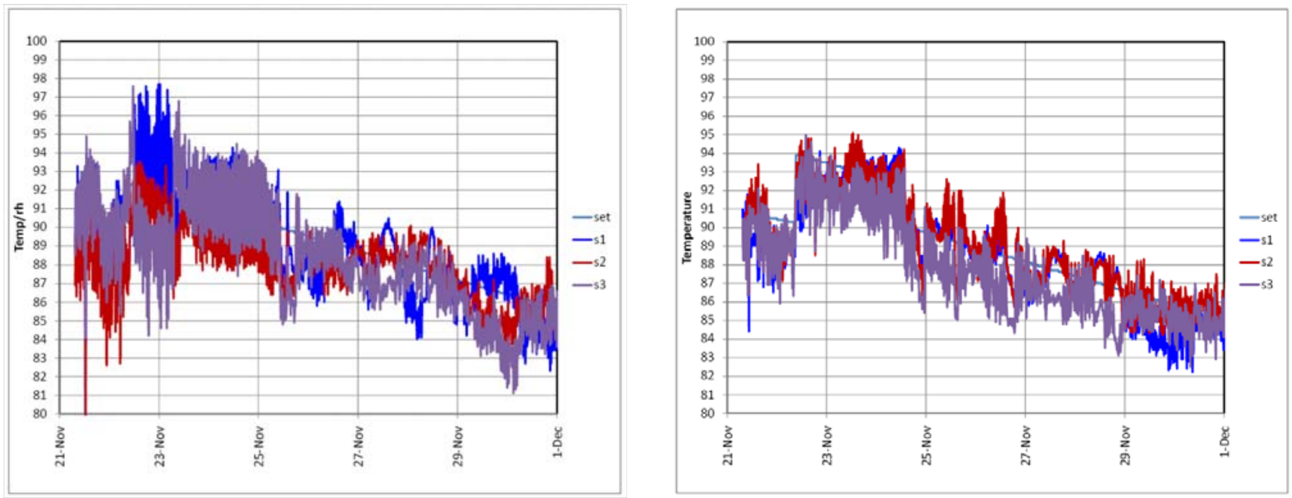

Figure 11. Temperatures in houses with alternative heating systems during brooding
(Perforated duct delivery system - left, Circulation fan delivery system - right)

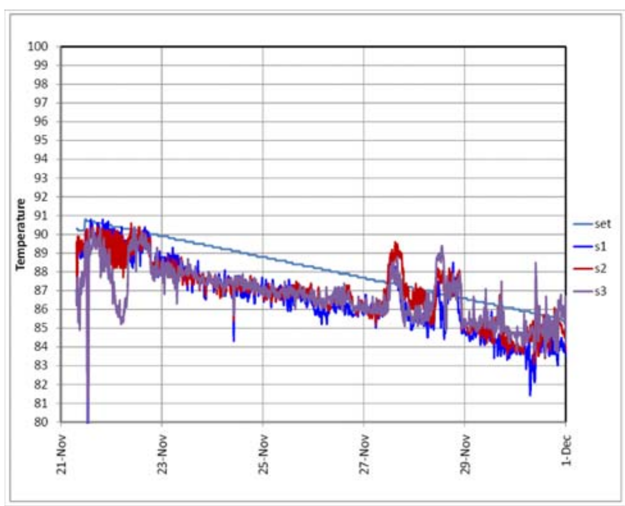

Figure 12. Temperature in control house with conventional radiant brooder heating system during brooding

8) During the first few weeks of the flock, the first stage of exhaust fans were set to operate three degrees above the controller set temperature. A hot-air alternative heating system will tend to continue to add heat to a house after the controller no longer calls for heat due to the fact that the blower needs to continue to operate for a short period of time to cool the burning unit to avoid damage. The fact that the heating unit continued to add heat to the house after it was shut off often caused the house temperature to rise a couple of degrees above the set temperature (Figure 11). Had the exhaust fans been set to operate only a degree or two above the set temperature, the fans would have come on shortly after the heating system shut off to cool the house down, which would have resulted in the heating system coming back on again. The constant battle between the exhaust fans and the heating system for control would have resulted in over-ventilation and an increase in heating costs. Later on during the flock when the offset for the alternative heating system was increased to three degrees, then the cooling offset for the first stage of exhaust fans was decreased to two degrees.

9) The Choretronics II controller, like many others, has a feature that will increase minimum ventilation settings as the house temperature begins to rise above the set temperature. This feature had to be deactivated when the alternative heating system was used due to the fact that when the alternative heating system caused the house temperature to rise

above the set temperature the minimum ventilation settings were increased, resulting in over-ventilation and increased heating costs.

The biggest challenge with operating a hot-air alternative heating system is maintaining a uniform house temperature. Variations in house temperature will significantly reduce the savings associated with alternative heating systems. Basically, if the entire house is the same temperature then the back-up propane heating system will never be called upon to heat a cold spot in the house and if the propane system is never used, heating costs will be minimized. Similarly, the more uniform the house temperature, the less likely an overly hot area will cause exhaust fans to come one, resulting in another area of the house becoming too cool, leading to the brooders coming on and an increase in heating cost. So in many ways, the key to fuel savings is the hot air distribution system. The better job it does at distributing the heat throughout the house, the less it will cost to heat the house.

To get an appreciation of the challenge of using a single heat source to heat an entire house, one day when your birds are in full house try to operate all the brooders/furnaces off an average of the all the temperature sensors in a house. What usually happens is that, unless your house temperature is perfectly uniform, one area will eventually become too hot and another too cold. Fans will start to come on to cool off the hot spots which will result in even cooler cold spots. After a period of time, though on "average" the conditions may be acceptable, much of the house will not be suitable for optimal bird performance and your operating costs will increase significantly.

Both the perforated distribution duct and the circulation fan system did an adequate job of distributing heat throughout the house. As one might suspect, distributing the hot air within the 250' brooding area was not that difficult. With an occasional tweak of the butterfly valves to throw more or less heat to either end of the brooding area, the producer was able to keep the brooding area within a few degrees resulting in a decrease in propane usage by 90%. It is important to note that part of the reason for the success in maintaining such uniform temperatures during the brooding phase of the growout was the fact that the houses were totally enclosed and equipped with insulated tunnel doors. Had the houses been curtain-sided, or totally enclosed with tunnel curtains, maintaining a uniform house temperature would have been more of a challenge and fuel savings would have likely been reduced.

Being able to effectively use the alternative heating system to preheat the nonbrooding end of the house as well as heat the nonbrooding end once the birds were turned out, resulted in significant heating costs savings. During our studies we generally found that it cost just as much to heat the house after the birds were turned out as it did when the birds were in half house. By being able to effectively use the alternative heating system during the entire flock our heat savings were effectively doubled. The biggest challenge encountered with heat distribution was during the first couple of days after the birds were turned out. Without the back up heat operating on the nonbrooding end, the tunnel fan area of the house ran five to ten degrees cooler than the brooding end. This is not an easy problem to solve for a couple of reasons. First, since the alternative heating system is positioned on the brooding end, it is difficult to heat the nonbrooding end sufficiently without at times overheating the brooding end. Secondly, until the birds start to move, the heat that they produce tends to add to the problem of overheating on the brooding end of the house.

It must be noted that though it was a challenge to deliver heat to the nonbrooding end without overheating the brooding end, it was not that costly of a problem. After a couple of days of occasional help from the forced air furnaces on the nonbrooding end the birds spread out and both the circulation fan system as well as the perforated duct system were able for the most part to maintain house temperature uniformity within five degrees. The success of the distribution systems is verified by the fact that flock propane usage was reduced by 80% or more in the houses utilizing the alternative heating systems when compared to the control houses. In fact, total propane usage, for the most recent wintertime flock (where nighttime lows were in the teens for much of the first week) averaged less than 75 gallons.

When using an alternative heating system, it is very important to realize that at times some areas of the house will run a few degrees above the set temperature in order to obtain proper temperatures in other areas of the house. This really shouldn't be viewed as a problem. Most of the time when we are adding supplemental heat the birds are young and being a few degrees above the "desired" temperature is really not a problem. For instance, if you have ten-day-old birds and the desired temperature is 84^{o}F, would bird performance really suffer if one area of the house is 87 or 88^{o}F? Of course not. To a young chick dropping below the target temperature a few degrees is more harmful than being a few degrees above it. The fact is that with a single heat source there will tend to be variations within the house of five degrees or possibly a little more. This amount of temperature variation is not harmful if the coolest spot in the house is near the desired temperature and not five degrees below it.

Another important point to keep in mind is that house temperature tends to vary more from minute to minute when using an alternative heating system than with a traditional propane heating system (Figures 11 and 12). How much house temperature will vary will depend on the response time of the alternative heating system as well as the distribution systems capability to rapidly deliver the hot air throughout the house. For instance, the alternative heating system we tested from a "cold start" was capable of delivering 150^{o}F air to the house in less than five minutes. This is approximately four times longer than the typical propane forced-air furnace. The greater response time, as noted previously, resulted in more of a temperature variation in the test houses as compared to the houses equipped with conventional propane heating systems. Though a four-minute response may seem fairly slow, we found it manageable. Had the response been greater, it is no doubt that the greater temperature variation would have resulted in increased heating costs as the house cycled between heating and cooling modes. Though it is true that the heating unit did not immediately stop producing heat once the house environmental controller stopped calling for heat, and did at times cause the house temperature to overshoot the set temperature by a degree or two, we found the problem easily manageable by make minor adjustments to the house's environmental controller settings.

It is important realize that the response time of the heat delivery system is equally important in maintaining uniform house temperatures. Though both heat delivery systems did a good job of distributing heat throughout the house, the circulation fan system appeared to be able to deliver hot air throughout the house a little faster than the perforated duct system, which resulted in a quicker heating system response time and less variation in house temperature over time. It is important to note that initially smaller 1/15 hp, 18" fans were used to distribute the hot air from the T-duct, which resulted in a slower response time and greater variations in house temperature. Had the perforated duct system had a larger blower, response time may have been faster, resulting in more uniform house temperatures. The point is that whether hot air from an alternative heating system is being distributed via a duct or circulation fans, the system must be properly designed to assure maximum temperature uniformity and fuel savings.

In conclusion, we found that an alternative heating system that uses hot air to heat a house can be designed to distribute hot air throughout a 500' long poultry house. The keys to reducing heating costs with these systems is to have a heating system with a quick response time, a hot air distribution system that can move the hot air produced by the burning unit quickly throughout the house, some way of directing the hot air in the house where it is needed, a tight well insulated poultry house, and a modern environmental controller capable of controlling all aspects of the poultry houses heating and ventilation system.

Michael Czarick
Extension Engineer
(706) 542-9041 542-1886 (FAX)
mczarick@uga.edu
www.poultryventilation.com

Brian Fairchild
Extension Poultry Scientist
(706) 542-9133
brianf@uga.edu

Devon Dartnell
Biomass Program Manager
Georgia Forestry Commission
ddartnell@gfc.state.ga.us
(706) 542-9219

Funding and support for this project was provided by the following organizations:
USDA Forest Service through a forest restoration woody biomass matching grant;
The One Georgia Authority in conjunction with the Georgia Agricultural Innovation Center;
FRAM Renewable Fuels, LLC - manufacturer of compressed wood pellets
University of Georgia - Extension Engineering
University of Georgia - School of Poultry Science
Georgia Forestry Commission