

FINAL REPORT

LONG-TERM MONITORING OF A TRANSPIRED SOLAR WALL ON A PIG NURSERY FOR ITS
ABILITY TO REDUCE HEAT ENERGY USE AND IMPROVE PIG PERFORMANCE (NC 67)

Submitted by:

Sanjay B. Shah and Trapier K. Marshall

NC State University, Raleigh, NC

and

Steve Matthis

Sampson Community College, Clinton, NC

28 JULY 2010

Acknowledgements

Many individuals and organizations aided in the completion of this project. The NC Pork Council funded the study. Prestage Farms, particularly, their nursery manager Mr. Alan Parker and Mr. Jeff Barnhill cooperated in the selection of the research site and supported the study. The study was conducted at the N&J Butler Farms, Clinton, NC, and its owners are thanked for their support to the project. Personnel from NC State University, namely, LT Woodlief, Craig Baird, Michael Adcock, Richard Currin, Phil Harris, and Carl Tutor provided critical support. Undergraduate students Casey Garland and Chris Love, both graduated, also provided valuable support. Advice from Isaac Singletary, Aerotech Fans is sincerely appreciated.

Abstract

High price of propane is a concern for pig nursery managers since raising nursery pigs is energy intensive. A transpired solar wall (TSW) could be used to warm the fresh air going into the pig nursery to reduce propane use. The TSW consists of a dark colored, perforated metal wall, which when heated by solar radiation, heats the air passing through it. A TSW (440 ft²) was installed on the south-side wall of a 1,520-pig nursery near Clinton, NC, in fall 2008 and its performance monitored during 2008-2010. This report presents findings observed during October 2009 through June 2010. Pig performance, energy use, internal conditions, and temperature rise at the inlet in the test nursery were compared to an identical, adjacent control nursery. The TSW was equipped with a bypass damper that opened to allow the fresh air to bypass the TSW when heating was not needed. Over the four herds monitored during 2009-2010, propane use was 25% lower in the test nursery vs. control nursery and the propane consumption per pig was 40% higher in the control nursery. Electricity use was 2.4% lower in the test nursery. During the heating cycle, air at the test nursery inlet was substantially warmer than the control inlet temperature. Eight percent more pigs in the test nursery could have reduced livability, daily weight gain, total weight gain, and feed conversion vs. the control nursery. However, for one herd when the test nursery had 6% more pigs than the control nursery but had fewer pigs than the nominal capacity (by 18%), pig performance was much better in the test nursery. Internal conditions (temperature, RH, and CO₂ concentration) were comparable in the test and control nurseries. During the hottest part of the day in warm weather, the TSW shaded the wall and reduced wall temperature, thereby reducing undesirable heat gain; however, averaged over the day, the shading effect was minimal. Over the monitoring period, the TSW reduced CO₂ emissions by 12,850 lb. The TSW had a simple payback period of 7.4 years without any incentives because propane was available at wholesale rate. An independent producer who has to pay residential price for propane will have a shorter simple payback period. With grants and tax credits, the payback period could be greatly reduced. There is possibility of improving the design to reduce cost and improve ease of operation.

Background

Raising feeder pigs is an energy intensive enterprise even in the relatively-warm climate of eastern North Carolina. A curtain-sided nursery housing 1,520 piglets in eastern North Carolina can consume >5,000 gallons of propane per year (Alan Parker, personal communication, 23 June 2008). The US Dept. of Energy (DOE) forecasted in August 2009 that residential propane prices during the 2009-2010 heating season would be ~14% lower than during the previous heating season in the south. However, the average price (based on weekly residential propane prices published by the DOE) in 2009-2010 was higher than the previous year by 7.4%. Propane prices are not only weather dependent, they can also be affected by political reasons and hence, continued volatility in the market can be expected. There is need for pork producers to continue to take steps to improve energy efficiency and reduce energy use.

The transpired solar wall (TSW) is a technology that can reduce energy use and as well as greenhouse gas emissions. The TSW consists of a dark colored, perforated metal wall, which when heated by solar radiation, heats the air passing through it. The air can be heated by as much as 63°F, depending on the orientation, cloud cover, and airflow rate through the wall. The TSW has solar energy conversion efficiency as high as 80% (vs. 15-20% for solar panels). The TSW can also improve environmental and indoor (unvented heaters) air qualities by reducing annual CO₂ emission by 40 lb/ft² of surface area when using natural gas (Conserval, 2008). With unvented propane or natural gas heaters, the TSW can also reduce indoor humidity since these fuels produce water vapor upon combustion. Apart from being the most efficient solar collector currently in the market, the TSW needs minimal maintenance (no moving parts). Hence, this R&D 100 Award-winning (NREL, 2006) has the potential to reduce heat energy use in livestock production considerably while improving pig performance through improved indoor air quality. NREL (2006) estimated that the TSW has a simple payback period of 3 years without any incentives.

Godbout et al. (2004) evaluated the impact of a TSW in a 1,000-head pig nursery in Quebec, Canada during the period November 2002 to April 2003. While they reported that propane energy savings ranged from 23 to 31%, no information was provided on pig performance. Deutsch (2007) reported that solar

walls reduced propane use by at least 25% in two pig nurseries in Quebec; even without incentives, the payback was less than 5 years. Transpired solar walls are widely used on Canadian farms; Solagra alone has installed them on more than 400 farms (Solag, 2008). There are no reports of TSWs being used on US animal farms.

The NCPC funded the installation of the first transpired solar wall (TSW) in a pig nursery at the N&J Butler Farm near Clinton, NC, in 2008 – 2009 (NC 67). Solar wall design, installation and some monitoring were undertaken during 2008-2009. In this project, modifications were made to improve data collection. The objective of this study was to evaluate the impact of a TSW on energy use and economics in a pig nursery near Clinton, NC. Simple payback was used to evaluate the economics of the TSW.

Materials and Methods

Description of the research farm

The research site is the N&J Butler pig nursery located near Clinton, NC, that contracts with Prestage Farms. The farm has two nurseries that were built in 1996, and each nursery (44 ft by 100 ft) has a nominal capacity for 1,520 pigs. Weaned piglets (~12 lb ea.) are placed at about 18 d and removed 45 d later at ~48 lb ea. Each nursery is populated over a 1-wk period and placement dates in the two nurseries vary by about 15 d. Both nurseries run approximately E-W and have 4 ft high and 80 ft long curtains on each of the sidewalls and insulated drop ceilings. Supplemental heating is provided by two propane forced air furnaces (225,000 Btu/h ea.). Minimum ventilation is provided by two variable speed 24 in. fans (Aerotech ATZ 24), whereas mild and hot weather ventilation are provided by four single speed fans (two 24 in. and two 36 in.). Fresh air is brought in through continuous sidewall inlets running the full length of both sidewalls.

Transpired solar wall construction

While the north nursery served as the control, the south nursery (experimental) was fitted with a 440 ft² black, galvanized TSW (medium airflow rate of 6.9 cfm/ft²) on the south side of the nursery, 5 ½ ft in height and 80 ft in length (fig. 1) in November 2008. As shown in Figure 1, the TSW structure covered

most of the south sidewall so that when the minimum ventilation fans came on, air pulled through the TSW was routed through the sidewall inlets. Prior to fall 2009, because both nurseries lacked tightness, the inlets did not open under minimum ventilation, and the south side inlet in the test nursery was kept ~1/2 in. open. Apart from allowing normal operation of the TSW, this opening allowed for the heat escaping through the south side wall to be recycled back into the building. However, after the houses were tightened in fall 2009, the south side inlet was raised to its normal position. Tightening included nailing the curtains at the bottom and installing flaps at the top of the curtain; these measures minimized heat losses through unplanned openings.

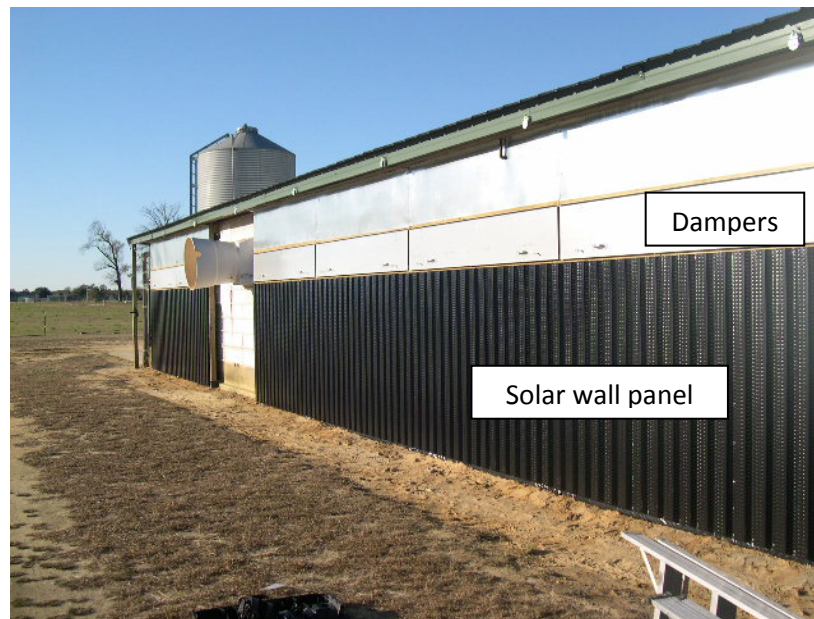


Figure 1. Solar wall installed on the south side of a pig nursery on the N&J Butler Farm near Clinton, NC

In the study by Godbout et al. (2004), the preheated air was distributed in the nursery through an overhead plenum installed in the attic; hence, it was convenient to bypass the solar wall during warm weather. However, since the fresh air in this study was drawn only through the sidewall inlets, ten 8 ft dampers that could open 12 in. were installed (fig. 1) to bypass the TSW when no heating was required. These dampers are simultaneously raised or lowered by a linear actuator through a system of pulleys and cable (fig. 2) based on the input from the nursery environmental controller. Whereas the dampers closed

at desired room temperature (DRT) minus 1 F, the heaters came on at DRT minus 2 F. The dampers are also designed to open in case of a power failure, concurrently with the curtain drop. The dampers can also be operated with a manual winch if necessary. The linear actuator is powered by a 12 V DC car battery that is charged by a trickle charger. While the winch and cable system was installed in early-December 2008, the installation of the linear actuator was completed in January 2009. The wiring to operate the linear actuator from the controller was completed in February 2009 in preparation with the onset of spring when the dampers would have to be raised on warm days. However, despite sealing with caulk, rainwater leaked into the limit switches during mid-February 2009 and rendered the actuator inoperable in the open position. After additional reconfiguration and repair, the actuator was made fully functional on 22 July 2009.



Figure 2. Picture of the linear actuator used to operate the dampers to bypass the TSW

Instrumentation and measurements

Temperature and relative humidity (RH) were measured every 15 min. inside a stilling well at a height of ~4 ft at the same location in both nurseries with a TinyTag Ultra sensor/data logger (Make: Omni Instruments, UK; ranges: -22 to 122 F and 0 to 95% RH; accuracies: ± 0.76 F and $\pm 3\%$ RH at 77 F). Hourly carbon dioxide (CO₂) concentrations were measured with a GMT220 sensor (Make: Vaisala,

Finland; range: 0 to 3,000 ppm; accuracy: $\pm 1.5\%$ of range plus 2% of reading) were measured alongside temperature and RH inside both nurseries and recorded on a Hobo U12-006 data logger (Make: Onset Computers, MA). The CO₂ concentrations provided information on the ventilation states of the two nurseries. Temperature and RH were also measured every second with a Hobo S-THA-M002 combination sensor (Make: Onset Computers, MA; ranges: -40°C to 75°C and 0% to 100% ranges; accuracies: $\pm 0.7^\circ\text{C}$ and $\pm 3\%$) at the air inlets of the two nurseries and averaged every 5 min on a Hobo H21-002 data logger (Make: Onset Computers, MA). When the temperature – RH sensor installed on the inlet of the control nursery malfunctioned, it was replaced with a TinyTag Ultra sensor/data logger that measured and recorded every 5 min.

One of two minimum ventilation (MV) fans in the experimental and control nurseries were equipped with Hobo motor on/off sensors (Make: Onset Computers, MA) to determine motor run times as affected by the solar wall. These motor sensors were installed in early-January 2009 since the original sensors provided by the manufacturer did not work on these fans and had to be modified in the BAE Dept. to increase their sensitivities. Used electric sub-meters with current transformers were installed in both nurseries to measure power consumption in late-November 2008; however, due to some undiagnosed problem, no meter readings could be obtained in the control nursery. New and more accurate electric meters were purchased with funds from another source and were installed in October 2009. Earlier, gas consumptions in the two nurseries were monitored based on separate gas bills provided by Parker Gas; however, to measure propane consumption more accurately, in October 2009, propane meters were installed in both houses with funds from another source. A wind vane – anemometer combination sensor S-WCA-M003 (Make: Onset Computers, MA; accuracies: ± 1.1 mph+3% of full scale reading and $\pm 5^\circ$) and solar radiation sensor S-LIB-M003 (Make: Onset Computers, MA; accuracy: greater of ± 10 W/m² or $\pm 5\%$) were installed ~100 ft from the solar wall in December 2008 to monitor wind effects and solar radiation receipt on the solar wall. These hourly wind speed, wind direction, and solar radiation measurements were recorded on a Hobo H21-002 data logger.

Pig performance data

Pig numbers, livability (%), daily and total weight gain, and feed conversion (lb of weight gained per lb of feed, %) were obtained from Prestage Farms for both houses. These parameters were compared between the two treatments to see if the solar wall affected pig performance.

Results and Discussion

Data collected during October 2009 through June 2010 are presented and discussed here. This 8-month monitoring period encompassed four herds of piglets.

Pig performance

Table 1 presents dates when pig placement dates and numbers, performance parameters for four herds in the control and test nurseries. As in 2008-2009, on average, the test nursery housed 8% more pig than the control nursery (Table 1). Further, pigs were kept, on average 2 d longer in the control nursery (Table 1). There was a long layover between herds 3 and 4 (table 1) probably because of market reasons.

Table 1. Pig populations and performance parameters^a for 4 herds in the control (Cont) and test nurseries.

Herd #	Date placed (duration of placement, d)		Total placed		Livability (%)		Daily weight gain (lb/pig-d)		Total gain (lb/pig)		Feed conversion ^b (%)	
	Cont	Test	Cont	Test	Cont	Test	Cont	Test	Cont	Test	Cont	Test
1	10/11/09 (48)	10/25/09 (45)	1506	1572	97.5	96.9	0.92	0.78	43.6	33.9	71.4	66.7
2	12/06/09 (46)	12/20/09 (45)	1496	1765	97.7	99.0	0.77	0.66	35.2	29.5	65.8	64.5
3	01/31/10 (47)	02/14/10 (47)	1563	1610	99.0	97.0	0.79	0.72	37.0	33.3	74.7	63.8
4	04/22/10 (57)	04/29/10 (54)	1166	1240	98.8	99.0	0.90	1.02	51.0	54.4	79.9	94.3
Mean	(50)^c	(48)	1433	1547	98.2	97.9	0.84	0.79	41.7	37.8	72.9	72.3

^aData provided by Prestage Farms

^bRatio of mass of live weight produced per 100 lb of feed consumed

^cMean duration of placement

Averaged over the four herds, livability of the pigs was comparable in the two treatments (Table 1) and very similar to what was observed in 2008-2009. The higher livability in the second herd in the test nursery was surprising because it had 18% more pigs than the control nursery (Table 1) but crowding likely impacted weight gain and feed conversion adversely. Averaged over the four herds, the control nursery had higher daily weight gain (by 6%), total weight gain (by 9%), and feed conversion (by 0.8%)

vs. the test nursery (Table 1). Higher pig populations in the test nursery may have reduced feed access reducing weight gain and feed conversion. Higher daily weight gain in the control nursery could be partly attributed to the longer duration of placement (50 d) in the control vs. the test nursery (Table 1).

The superior performance of the test nursery for the 4th herd with respect to daily weight gain (by 13%), total weight gain (by 7%), and feed conversion (by 18%) (Table 1) may be due to fewer pigs (1,240) than the nominal capacity (1,520 pigs). However, the test nursery still had 6% more pigs than the control nursery. Averaged over the four herds and based on total initial numbers placed, livability, and total weight gain, the test nursery produced 55,479 lb of live weight per herd vs. 57,886 lb for the control nursery (data not presented). Hence, as also observed during the 2008-2009 evaluation, it seems unlikely that the TSW adversely impacted pig performance due to excessive heating or reduced ventilation.

Propane consumption

Due to the use of propane meters in the two nurseries, propane use was monitored much more accurately. During 16 October 2009 through 28 May 2010, propane consumption in the test nursery was lower than the control nursery by 25% (Fig. 4). The reduction observed in this study is in line with those reported by Godbout et al. (2004) and Deutsch (2007) in two nurseries in Quebec. The control and test nurseries required 0.70 and 0.50 gallons/pig of propane during this period. Hence, the control nursery required 40% more propane than the test nursery on a per pig basis.

To account for the effect of different ambient temperatures due to difference in placement dates and different durations of placement in the test and control nurseries on propane use, heating degree days (HDDs) were calculated. Since heating starts prior to pig placement and heating needs decrease as the pigs grow older, HDDs were summed up 1 d prior to pig placement and 20 d during placement for a total of 3 weeks for each heard. First, average daily temperature for the relevant periods were calculated from hourly air temperature obtained from the NC CRONOS weather station at the Horticultural Crops Research Station, Clinton. The HDD for a day was calculated by subtracting the average daily temperature from the baseline temperature (65 F), only if the baseline temperature was higher. For the

four herds from October 2009 through June 2010, the HDDs were 1280 and 1325 for the control and test nurseries, respectively. Hence, it is clear that the based on placement dates and durations of placement, the test nursery was subjected to conditions requiring greater heating than the control nursery. If the control nursery had the same HDD as the test nursery, it would have consumed propane and the difference between the two nurseries would have been greater.

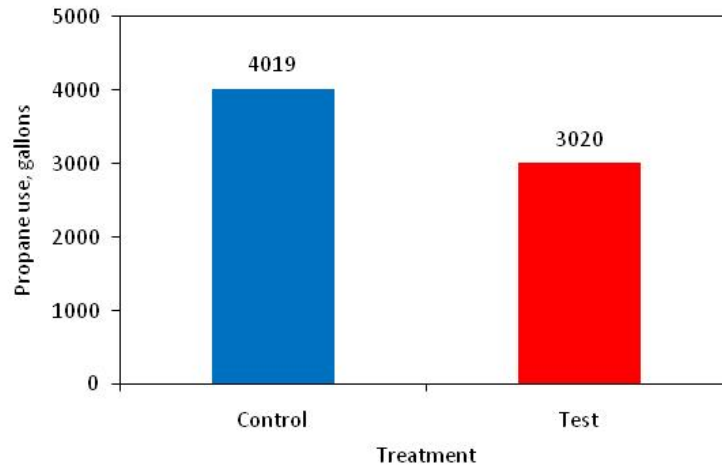


Figure 4. Propane use in the control and test nurseries during 16 October 2009 through 28 May 2010.

For the last herd, pigs in the control and test nurseries were 36 and 29 d old, respectively, on May 29 and it was assumed that they did not require any more propane for the rest of duration.

In 2008-2009, when propane consumption in the two treatments were tallied based on gas receipts from Parker Gas (Clinton, NC), the test nursery had consumed 20% more propane than the control nursery. Hence, it seems that there was an error in tallying the gas receipts since the propane consumption readings on the nurseries gave much more accurate readings.

Electricity consumption

There was concern that use of the TSW could raise electricity consumption due to increased pressure drop that would reduce airflow rate and increase fan run time. During 16 October 2009 through 6 May 2010, electricity use was 10,440 units in the test nursery vs. 10,700 units in the control nursery. While a reduction of 2.4% electricity use in the test nursery may not be a major saving, it positively affects the

economics of the TSW. Reduction in electricity use could have been due to reduced operation of the centrifugal blower in the propane heater.

Environmental impacts

Since propane use was reduced by 1001 gallons in the test nursery, emissions of CO₂, a greenhouse gas was reduced by 12,512 lb since the combustion of 1 gal of propane releases 12.5 lb of CO₂. Based on DOE (2000) estimates, 1.3 lb of CO₂ is emitted per kWh of energy generated. So, the reduction in CO₂ emission due to 260 fewer units of electricity used would amount to reduction in CO₂ emission by 338 lb. Hence, use of the TSW resulted in reduction in CO₂ emissions by 12,850 lb.

Internal conditions

Temperature: Average internal and ambient (NC CRONOS data) temperatures are compared by herd between the control and test nurseries in Table 2. The test and control nurseries had comparable internal temperatures for herds 1 and 2 despite differences in ambient temperatures (Table 2) and pig populations (Table 1). For herd 3, despite higher ambient temperature, the test nursery ran 1.3 F cooler (Table 1) but this difference is within the combined accuracy of the two sensors (± 1.52 F or ± 0.76 F per sensor). For herd 4, the test nursery was warmer by 1.8 F, comparable to the higher ambient temperature for the test nursery placement vs. the control placement (Table 2); it may also be noted that the test nursery had 6% more pigs than the control nursery for this herd (Table 1). Hence, the TSW did not cause overheating in the test nursery which supports the findings of the analyses performed during the winter of 2008-2009.

Table 2. Average^a ambient and internal temperature (F) by herd.

House	Herd 1		Herd 2		Herd 3		Herd 4	
	Ambient	Internal	Ambient	Internal	Ambient	Internal	Ambient	Internal
Control	56.3	84.0	39.9	84.4	42.3	84.0	73.0	85.1
Test	54.0	84.2	38.9	83.8	49.0	82.8	74.7	86.9
Test-Cont	-2.4	0.2	-1.0	-0.6	6.7	-1.3	1.7	1.8

^aObtained by averaging all logged internal and hourly ambient temperature values during herd placement

Relative humidity: Since RH can affect pig performance (Eisenmenger, 2003), average internal and ambient RH values by herd are presented in Table 3. Both nurseries had similar RH levels and the herd-

wise difference was less than the combined accuracy ($\pm 6\%$) of the RH sensors in the control and test nurseries. Since the test nursery had more pigs (Table 1) and the heaters were vented, higher internal RH values had been expected than in the control. The average internal RH values were $<65\%$ and are thus considered to be not harmful to herd health (Eisenmenger, 2003).

Table 3. Average^a ambient and internal relative humidity (%) values by herd.

House	Herd 1		Herd 2		Herd 3		Herd 4	
	Ambient	Internal	Ambient	Internal	Ambient	Internal	Ambient	Internal
Control	85.7	60.8	73.8	46.6	71.2	51.0	70.9	55.8
Test	85.0	60.1	74.0	46.4	66.2	47.4	72.0	58.1
Test-Cont	-0.6	-0.7	0.2	-0.2	-5.0	-3.6	1.1	2.3

^aObtained by averaging all logged internal and hourly ambient RH values during herd placement

Carbon dioxide concentrations: Internal CO₂ concentrations are indicative of the ventilation status of the structure and high CO₂ concentrations can impact pig performance. Average CO₂ concentrations by herd are compared between the two treatments in Table 4.

Table 4. Average internal CO₂ concentration (ppm) by herd.

House	Herd			
	1	2	3	4
Control	1,855	2,343	2,418	1,075
Test	1,864	2,435	2,107	991
Test-Control	9	92	-311	-84

From Table 4 it is clear that the difference in CO₂ concentrations between the treatments is negligible for any of the herds since it is much lower than the combined accuracy of the two sensors. With more pigs, CO₂ concentrations would have been higher in the test nursery but increased ventilation rate may have diluted the house air resulting in comparable CO₂ concentrations between the two treatments. Table 4 clearly shows the impact of the season (Table 1) on ventilation rate and hence, CO₂ concentration.

Inlet temperature

Calculating the heating effect of the TSW, through both heat recycling and solar radiation is complicated by the difference in pig placement numbers and dates in the control and test nurseries. On

different dates, the ambient temperatures were different. Intermittent failure of sensors and data loggers also added to the challenge. However, there were days when the pigs were within 2 d of age in the two houses when average daily ambient temperatures were within 2 F. Inlet (10-min), ambient (hourly), and desirable room temperature (DRT) data for such a day is presented in Fig. 5 for both treatments.

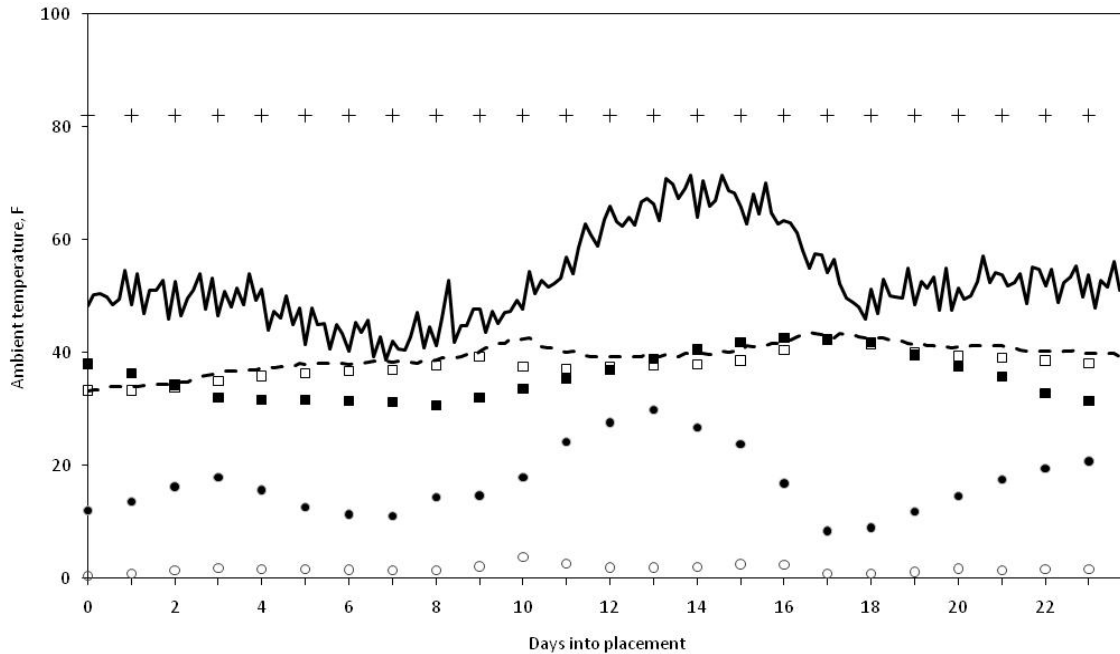


Figure 5. Comparison of hourly inlet temperatures in the test (solid line) and control (dashed line) houses, ambient temperatures in the test (filled square) and control (open square) houses, temperature rise at the inlet in the test (filled circle) and control (hollow circle) houses, and desirable room (+) temperature in the test and control houses on 2 and 16 Feb., 2010, respectively. Pigs in both houses were 2 d of age.

The average daily ambient temperatures were 37.7 and 35.9 F, respectively, in the control and test houses on 2 and 16 Feb. 2010 (Fig. 5) and the pigs were 2 d of age in both houses. The TSW increased the air at the inlet by ~30 F at 1:00 pm (Fig. 6) showing that it is very effective in tempering air passing through it. On average, temperature rise at the test house inlet for that day was 17 F compared with <2 F at the control house inlet. There is a substantial heating effect of the TSW even in the early morning and late night periods due to the TSW's ability to recycle heat through the curtain walls. It seems that even

without the TSW, the inlets recycle some heat since compared to the ambient temperature, the control inlet temperature rose by 4 F at 10:00 am (Fig. 5).

Total energy gains were also calculated for the test and control nurseries (only south-side vents) for herd 3, day 2. It was assumed that the south-side vents provided 50% of the total ventilation for the test and control nurseries. It was assumed that on day 2, the control and test nurseries had 1,563 and 1,610 pigs, respectively (Table 1); hence, mortalities were neglected. It was also assumed that cold weather ventilation was provided at 2.5 cfm/pig (MWPS, 1993).

Based on the above assumptions, on day 2 of herd 3, total energy added by solar radiation and heat capture in the test nursery was 2.04 million Btu. By comparison, the control nursery gained 0.22 million Btu through heat capture and roof radiational heating. Hence, the test nursery saved or generated 1.82 million Btu that day which is equal to 19.9 gallons of propane saved. Reduction in propane consumption reduced CO₂ emission by 249 lb. However, it may be noted that on 16 Feb., the air was much drier (58% relative humidity) vs. 87% on 1 Feb. If the ambient air relative humidity had been 87% of 16 Feb., heat added would have been lower by ~1/4.

Wall heating effect during hot weather

There was some concern that covering the sidewall of the house with TSW could warm the wall surface resulting in undesirable heat gain in the building. Figure 6 illustrates the temperature profiles behind the TSW ('shade') vs. exposed ('sun') collected with thermocouples placed close to one-another. Both under warm (22 June 2009) and mild (1 April 2010) conditions, the TSW prevented the sidewall surface from getting too hot during mid-afternoon (Figure 6). During the warmest part of the day, the TSW reduced the surface temperature by as much as 15 F, thereby reducing heat gain in the building substantially when the pigs would be the most heat-stressed. However, at other times of the day, the surface shaded by the TSW got somewhat warmer than the exposed surface probably because it could not dissipate heat as fast as the exposed surface. It may be noted that the thermocouple measuring the temperature behind the TSW was located below the damper so even when there is airflow through the

raised damper, the thermocouple does not experience convective cooling. Averaged over the 24-h period, on both days (Figure 7), the exposed and shaded temperatures were within 0.5 F. So, while the TSW may not provide net cooling, it does reduce heat gain into the building during the warmest time of the day.

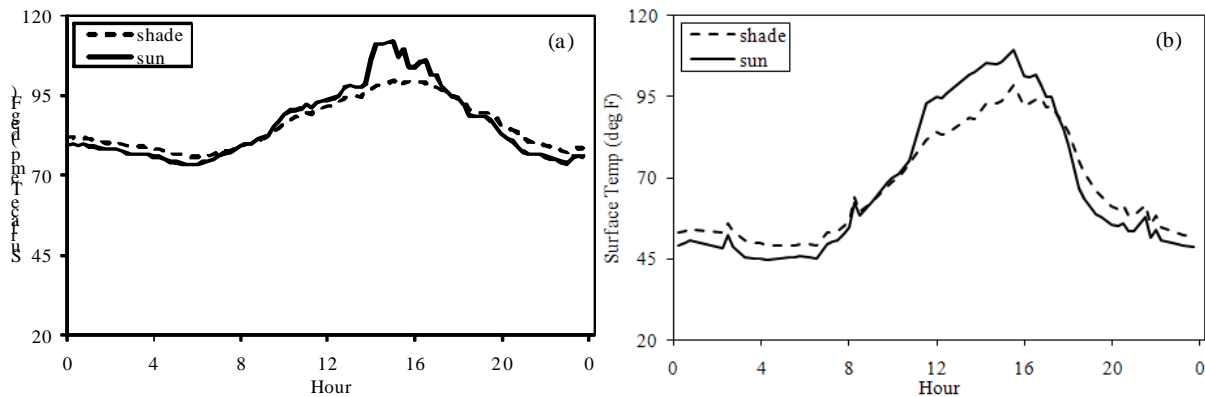


Figure 6. Shading effect of the TSW on the test nursery sidewall. Shade indicates temperature behind the TSW and sun indicates exposed. Both sensors were adjacent to one-another. Data for (a) 22 June 2009 (average ambient air temperature 76.7 F) and (b) 1 April 2010 (average ambient air temperature 63.7 F).

On both days, the pigs were 1 d away from being removed.

Economics

Based on invoices, it is estimated that material cost would be about \$8,000 plus 6.75% tax at that time. So, the total cost for materials would be \$8,540. Cost of the lumber framing by a contractor was \$1,000. Labor contributed by BAE Dept. personnel was estimated to be ~\$2,500. So, the total project cost was ~\$12,000. Saving in propane and electricity during the heating season were 1,001 gallons and 260 kWh, respectively. Based on a wholesale price of \$1.60/gallon for wholesale propane charged by Parker Gas to Prestage Farms (D. Parker, personal communication, 28 July 2010) and 11.6 cents/kWh for electricity, the savings would be ~\$1,630. Hence, without any incentives, simple payback would be 7.4 years (total price ÷ saving/yr). This simple payback period is higher than the payback of 3 years reported by NREL because the propane supplier was charging the integrator (Prestage Farms) a wholesale price of much lower than the residential price that NREL used for calculating the simple payback period. Further,

the use of a complicated damper system accounted for ~1/3 of the total cost, resulting in a longer payback period. Simplifying the damper system would considerably reduce the total cost as well as the simple payback period. If an independent producer had to buy propane at the residential price (~\$2.62/gallon per DOE in 2009-2010), the simple payback period would be much shorter.

The simple payback period of 7.4 yr calculated above does not take into account any government incentives. The USDA Rural Energy for America Program (REAP) provides grants of up to 25% of total project cost. However, there are Federal (30%) and NC (35%) tax credits as well. The Federal tax credit also applies to the portion received as USDA REAP grant. So, payback period could easily be halved.

This project has shown that there are substantial reductions in CO₂ emissions and if carbon credits were to be given or CO₂ emissions were to be taxed, the economics of this system would be more favorable. Finally, there is potential to improve the design of the system to bring down its total cost and make operation easier.

Summary and Conclusions

A transpired solar wall (TSW) (440 ft²) was installed on the south-side wall of a 1,520-pig nursery near Clinton, NC in fall of 2008. To prevent excessive heating during warm weather or with larger pigs, the TSW was equipped with a bypass damper that opened to allow the fresh air to bypass the TSW when necessary. Pig performance, energy use, internal conditions, and temperature rise at the inlet in the test nursery were compared to those in an identical control nursery located adjacent to it during November 2008 through June 2009 and again during October 2009 through June 2010. Some important conclusions based on monitoring performed during October 2009 through June 2010 are summarized below.

1. Propane use was 25% lower in the test nursery vs. control nursery. Per pig propane consumption was 40% higher in the control nursery.
2. The TSW reduced electricity use by 2.4% over a 7-month period.
3. Internal conditions (temperature, RH, and CO₂ concentration) were comparable in the test and control nurseries.

4. During winter, air at the test nursery inlet was substantially warmer than the control inlet temperature. During warm weather, with the bypass damper open, the test and control inlet temperatures were comparable.
5. For herd 3, day 2, when the ambient control and test temperatures were comparable, the TSW supplied 1.82 million Btu of energy resulting in saving of 19.9 gallons of propane.
6. During the monitoring period, the TSW reduced CO₂ emissions by an estimated 12,850 lb due to reduced propane and electricity use.
7. The TSW reduced heating of the sidewall during the hottest part of the day in warm weather, thus reducing undesirable heat gain. However, averaged over the day, temperatures behind the TSW and exposed to the sun in warm weather were very similar.
8. Over the four herds monitored, the test nursery had 8% more pigs than the control nursery. Crowding in the test nursery could have reduced livability (-0.3%), daily weight gain (-0.05 lb/d), total weight gain (-3.9 lb/pig), and feed conversion (-0.6%) in the test nursery. In the 4th herd, despite having more pigs than the control nursery, because the herd size in the test nursery was smaller than its nominal capacity (by 18%), it outperformed the control nursery in daily weight gain, total gain, and feed conversion.
9. Without any incentives, the TSW has a simple payback period of 7.4 years.

There is need to simplify the design of the TSW to reduce cost and ease operation. There is also need to evaluate the TSW in a house with unvented heaters and where animal placement numbers and dates can be closely matched between the test and control houses.

References

- Conserval. 2008. SolarWall case studies – German case histories (solar air heater system). (<http://www.scribd.com/doc/2095642/SolarWall-Case-Study-German-Case-Histories-solar-air-heater-system>)
- Deutch, S. 2007. Solar walls save money. *National Hog Farmer*. Nov. 15, 2007 issue.
- DOE. 2000. Carbon Dioxide Emissions from the Generation of Electric Power in the United States. Washington, DC: DOE and EPA. (http://www.eia.doe.gov/electricity/page/co2_report/co2emiss.pdf)
- Eisenmenger, M. 2003. Strategies to control enteric pathogens. *National Hog Farmer*. Oct. 15, 2003 issue.
- Godbout, S., F. Pouliot, I. Lachance, H. Guimont, R. Leblanc, F. Pelletier, and L. Hamelin. 2004. Feasibility and energy recovery of a solar wall in pig nursery. Paper No. 044140. St. Joseph, MI: ASAE.
- NREL. 2006. *Solar buildings: Transpired Air Collectors, Ventilation Preheating*. Washington, DC: National Renewable Energy Laboratories (NREL) for Dept. of Energy
- Solag. 2008. Solagra – something new under the sun. (<http://www.solag.net>)