RESEARCHREPORT

ENVIRONMENT

Title: Integrated GHG Emissions and Tradeoff Cost Model for Swine Barn Operations – **NPB #11-086**

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Executive Summary

In 2009 the National Pork Board (NPB) funded a group at the University of Arkansas to develop a greenhouse gas (GHG) calculator that would estimate the total emissions from all significant sources in a swine barn operation. This first phase concluded in March 2011 with the release of Live Swine Carbon Footprint Calculator Version 1, which was distributed freely beginning in June 2011. That calculator was designed to estimate the amount and sources of greenhouse gas (GHG) as CO_{2e} emissions associated with swine production activities. The calculator included separate models for sow barns and grow barns, the latter covering nursery, nursery/finish and grow/finish operations. The program was designed to run on a PC and no data were sent through the internet or stored within the program. It was the most comprehensive GHG emissions calculator in agriculture. However, the model did not estimate the economic costs associated with these activities that generate emissions. By adding economic cost components, both emissions and costs can be compared across multiple production strategies so that cost-effective methods to reduce farm-level GHG emissions may be identified.

In 2011, the University of Arkansas was awarded a grant from the National Pork Board to facilitate the development of Version 2 of the Calculator which would include the development of an economic component and further improve its overall capabilities and scope. Specifically, the work promised consisted of three tasks:

- **Upgrade Version 1** with a translation of all code from MatLab to C# and improve the GHG emissions code to include a wider range of manure handling systems, feeds, temperature control strategies, barn constructions and other types of hardware and operational variations not covered in Version 1.

- **Create and add in the economic model** to calculate the costs associated with activities that generate GHG and also asses the cost (or reduction in cost) associated with reducing the carbon footprint of swine production operations.

- **Improve the animal physiology model** to better link animal feed, growth rates, and manure production/composition.

Version 2 of the calculator, (now titled the Pig Production Environmental Calculator) was delivered on time to the National Pork Board late May 2013. This version contained most of the specified upgrades including:

- Translation of the code from MatLab to C# for faster runtimes and better compatibility with a wide range of computers.
- Development of an improved Excel-based, user friendly interface that allows input scenarios to be saved and results to be printed.
- Development of a detailed user guide with step by step instructions for data input and explanations of all model output.
- Addition of water usage and GHG emissions from its acquisition and distribution, counties expanded to match the 2010 census, and addition of code for emissions due to manure delivery and application.
- Improvements to the animal physiology model.
- Expansion of the available feeds for diet development to 162 ingredients
- Integration of an economic module that calculates costs associated with production activities that generate greenhouse gas emissions
- Integration of a comparison module that calculates the changes in emissions and costs that result when production activities are changed

We intended to include DNDC into Version 2 but the DNDC group was unable to provide working code in time for it to be added to the project. We instead utilized our own set of manure system Tier 2 models for subfloor, deep pit, lagoon and outside storage. Without DNDC we could not include emissions after field application, although we were able to calculate emissions from manure transport and land application. In the proposal we indicated that we would perform a substantial update to the animal physiology equations. Some of that was accomplished for Version 2 but the inclusion of NRC equations was not completed by the release date. However, the NRC equations have been successfully added to the model under this contract period and will be in Version 3.

Additionally we have provided educational opportunities for two PhD students, three MS students and two undergraduate student throughout the project. Fifteen oral and poster presentations have taken place or been accepted related at regional, national and international professional meetings. The Calculator will be used extensively in an undergraduate environmental economics class in Spring 2014. Journal articles are targeted for submission early in the new year. Details related to these activities are described in the report below.

1. Capabilities of the Calculator

The Pig Production Environmental Footprint Calculator Version 2 operates at a high temporal resolution and on the level of individual animals by keeping track of the weight, feed intake, manure production, heat production and reproductive behavior of every pig on a daily basis. Each pig that passes through the barn is tracked in this way and the sum of all animal feed consumption and manure production is used in calculating greenhouse gas emissions for the barn. Emissions from heating and cooling the barn are calculated by considering the local hourly temperature and relative humidity of the farm from a large climate database of locations in the U.S. The model predicts emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), the most important agricultural greenhouse gases, and day-to-day costs from eight areas: feed production, feed delivery, manure handling, electricity, heaters, fuels, water, and disposal of dead animals. As a result, you can:

- identify emission hot spots in existing operations,
- identify areas of substantial day-to-day costs in existing operations, and
- evaluate the effects of a modified day-to-day activities and barn design to emissions and costs.

The model covers one barn and its associated manure system. Users can choose from four available barns: grow, sow, gestation and farrowing. The grow barn can be a nursery-finish, grow-finish or feeder-finish barn depending on the inputs. It was written for CAFO systems and does not simulate pasture-based operations. The model takes into account the upstream burden of feed production for the barn, burdens within the barn such as heating and cooling, water usage, lighting, piglet heaters, incidental fuels and dead animal disposal. Emissions are calculated for manure handling systems (subfloor, deep pit, outside storage, lagoon) and transport of manure to the fields by truck or hose. Emissions are not calculated for manure application to the fields or for emissions from manure on the fields. Emissions are calculated from cradle to farm gate. Costs are calculated for the day-to-day expenditures associated for the eight areas listed above.

The software is designed for minimal user input. While descriptions of the barn operation that are centered on hardware facilities, herd size and methods of barn operation are required to be entered the model will predict the amount of feed that will be consumed, the electricity required, manure produced or fuels used and the costs of these activities. This approach allows for evaluation of both existing and hypothetical scenarios. This is made possible by the model's highly detailed approach in both time resolution and herd characteristics. At the model's core is a demographic sub-model that tracks every pig in the barn every day rather than taking an average-animal approach. Each pig is tracked individually from the time it enters the barn until it dies or is culled. Piglets in the sow barn are tracked from farrowing until removal at a weight you specify. For every pig every day it calculates, based on peer-reviewed animal models, the feed intake, daily weight gain, manure production, nitrogen in manure, volatile solids in manure, and heat production. Some stochastic elements are used in the model where appropriate. For instance, the age distribution of gilts arriving at the sow barn is randomly distributed over an expected range, insemination success is calculated with a probability generator, and pigs that die in the barn are selected at random.

The model calculates fan electricity and the use of natural gas or liquid propane heating fuels by performing a barn heat balance every hour of the year. This heat balance includes production of heat by the pigs, again based on animal models, hourly outside temperature and relative humidity for the farm's location, vapor venting requirements, lighting, piglets heaters, cooling cells, and your description of the fan system. It then calculates the required electricity and fossil fuels based on algorithms used by automatic barn temperature control units in use today.

At the end of a simulated year, the model adds up all of the energy and material input streams along with the manure output streams and switches away from the demographic sub-model into a module that calculates the resulting CO_2, CH_4 and N_2O emissions. These calculations are based on the carbon footprint of electricity, fossil fuels, and feeds. Emissions from manure are calculated for the system you selected including slurry-base methods such as shallow-pit, lagoon, deep-pit, and outside storage. The manure models were selected from temperature-dependent kinetic models for the slurry systems in order to capture the effects of local climate on emissions.

At the same time, the model uses those totaled energy and material input stream values as well as user selected energy and input prices to calculate total day-to-day costs associated with these activities over the course of one year. The end result is a list of the lb CO_{2e}/year and $/year associated with the various parts of the swine production operation as well as a grand totals. Sensitivity analyses can be conducted by changing one or more of the scenario inputs and rerunning the model. This new output – under the comparison scenarios – will highlight changes in GHG emissions and costs associated with the changes in activities.

2. Project Tasks – Improvements to Version 1

2.1 Translation from MatLab to C#

Version 1 was written in MatLab and this produced a number of issues in the implementation of the model on a CD-deployable platform. An interface had to be written by a third-party software developer, the resulting code was slow since MatLab is an interpreted language rather than a compiled language, and installation on the user's machine required the installation of additional software to facilitate running MatLab code.

A priority for Version 2 was to translate the model into another language that would avoid these problems. The clear choice was some variant of C since this class of languages is readily compiled on any platform, is very fast, and is widely used to create user interfaces. After evaluating the various dialects C# ("C sharp") was chosen. It is the same language that the third-party software consultants used to write the interface for Version 1. About 4,700 lines of code were translated but only a few of the basic algorithms had to be changed. Much of the MatLab model could be pasted into the new language's editor and modified into usable C#.

Once translated into C#, the same code ran much faster. For example, the sow barn model required 3.75 minutes (225 seconds) in MatLab but less than 15 seconds in C#. Subsequent model enhancements have expanded the final code to over 6,000 lines but the full model still runs in 5 to 30 seconds, depending on the capabilities of the computer.

2.2 Model Interface

University of Arkansas personnel developed the user interface for the Pig Production Environmental Calculator. The final software program is compatible with Windows Vista, XP, 7 or 8 and relies on Excel 2007, 2010 or 2013 as the platform for the user interface. The calculator is run from an Excel spreadsheet. This platform was chosen because it was very easy to implement, very flexible and can be made esthetically attractive (see Figure 1 below). The interface is a sophisticated spreadsheet that uses floating input forms so that it closely resembles the interface in Version 1 rather than the spreadsheet that it is.

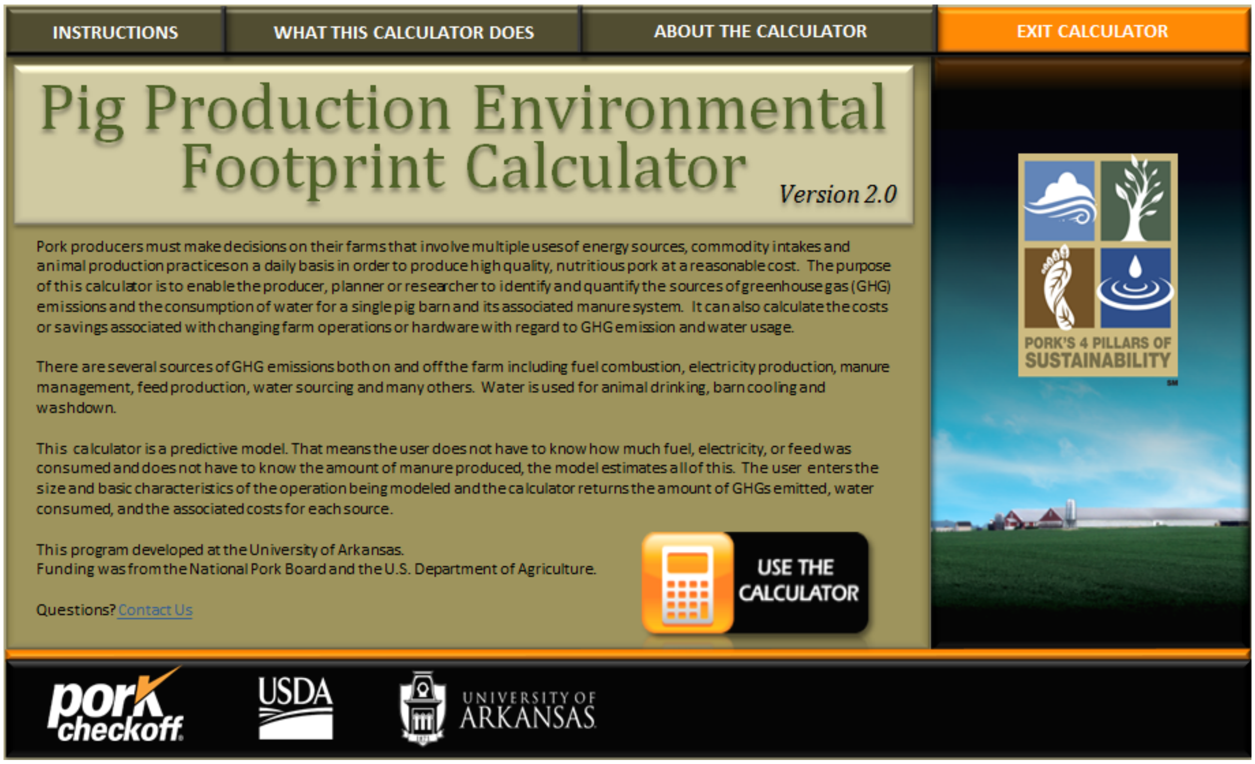


Figure 1. Calculator Home Page

2.3 Improved County Set

We used 2010 U.S. census data to create a more accurate updated list of state + county options for the user. We now list 3102 counties in 50 states + the District of Columbia. These "counties" includes variations such a parishes and boroughs where applicable. These are individually linked to the same 630 climate database stations used in Version 1.

2.4 Improvements to Heating and Cooling

As described above, the calculator takes into account ventilation fans for both cooling and vapor removal, heat from natural gas or propane, conduction through walls and roof, heat generated by the animals themselves and any optional water drip or spray that the user might specify. Water drip or spray was new to Version 2. We studied actual pig barn heating/cooling systems and modeled ours to match. Every hour, the program calculates what the temperature in the barn would be if there was no supplemental heating and no fans above those running at the minimum rate to remove vapors. If this temperature is within the upper and lower temperature limits for the barn, then no supplemental action is taken. If not, either the heater or fans kick in at the minimum amount to bring the barn temperature within limits. This minimizes the total energy - and emissions - from barn climate control and, for that reason, is the same control strategy used in practice. The barn types were expanded to include drop curtain and hoop barns in addition to fully tunnel-ventilated structures.

2.5 Improvements to Manure Systems

Version 2 was a barn-level model in that each barn had its own dedicated manure handling facility, either subfloor followed by lagoon or outside storage, or deep pit under the barn. We used temperature-dependent kinetic models from peer-reviewed literature to create time-dependent models of methane production from these units. Emissions from manure handling and emissions from feed production are the two largest contributions to the overall quantity and those from the manure systems are very sensitive to temperature. By utilizing Tier 2 models along with the calculated barn temperatures described above, we were able to capture this effect. Nitrous oxide emissions were handled with a Tier 1 approach.

2.6 Addition of Water Usage and Water Footprint Calculations

One key thing that makes this model different from most other GHG calculators is that the Pig Production Environmental Footprint Calculator predicts the usage of water, diesel, gas, and electricity on the farm rather than have the user enter the amounts consumed each year. This additional layer of granularity and flexibility gives enables us to take into account secondary effects that the other models can't see. Version 1 lacked some of this capacity in that it required to user to enter the number of gallons per year of water consumed and only predicted water usage for cooling cells (evaporative cooling). The cooling cell model is a fairly rigorous thermodynamic model that takes into account the dry and wet bulb temperatures and assumes that the incoming air is lowered to its adiabatic saturation temperature. The use of cooling cells is user-selectable and is triggered by exceeding a specified outside temperature.

in Version 2 users can calculate water emissions and costs associated with water acquired from wells, piped in sources, and other means such as lakes, rivers or on-farm holding ponds. Users also provide relevant horse power and flow rates of pumps associated with water acquisition and distribution (see Figure 2 below).

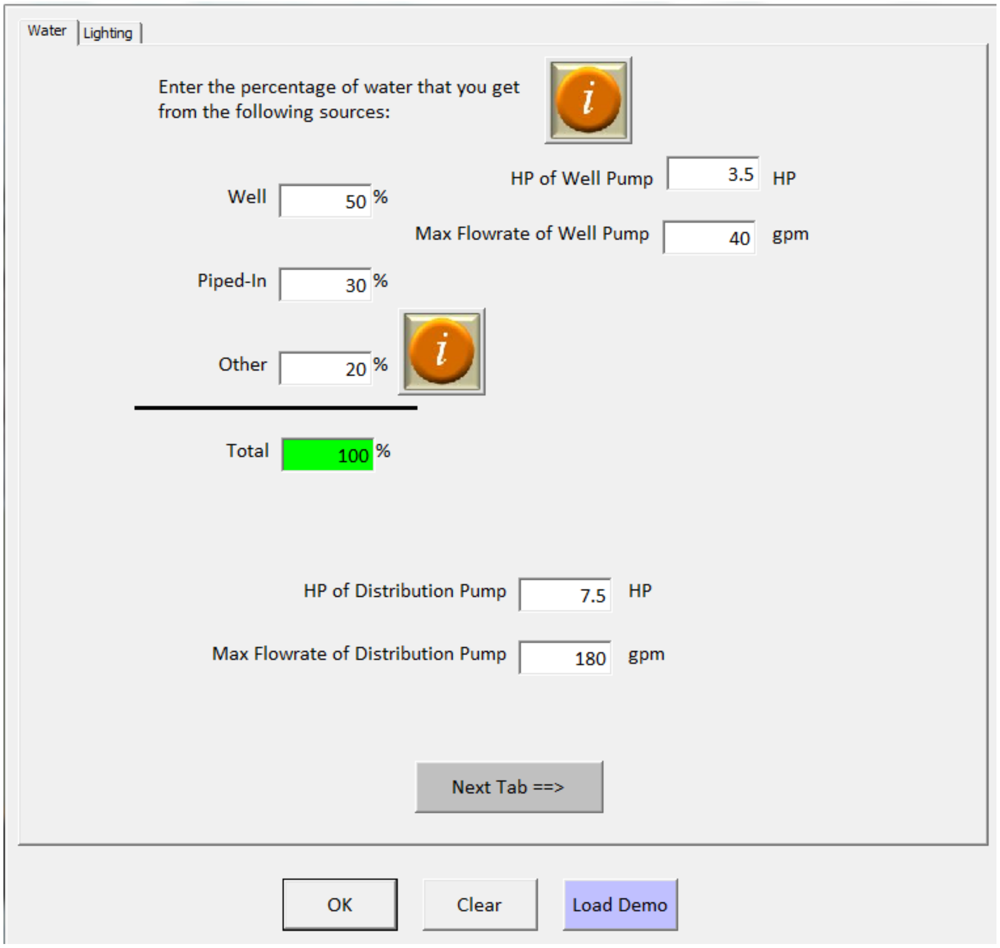


Figure 2. Water Input Screen

New algorithms were also added that predict the amount of water drunk by pigs and the amount used in drip or sprinkler cooling systems. Drinking water takes in account the pig's weight, gender, lactation status and gestation status. The CO_{2e} emissions are calculated from the amount of water used and from its source, well or piped-in from municipal sources. If well water is used, the program calculates the energy requirements to pump the water up from a user-specified depth. Carbon footprint estimates are reported individually for water acquired as well as water used on –farm (see Figure 3). Carbon footprint estimates for well water were calculated from the energy needed to lift the water out of the ground and the emissions for piped-in water came from literature sources.

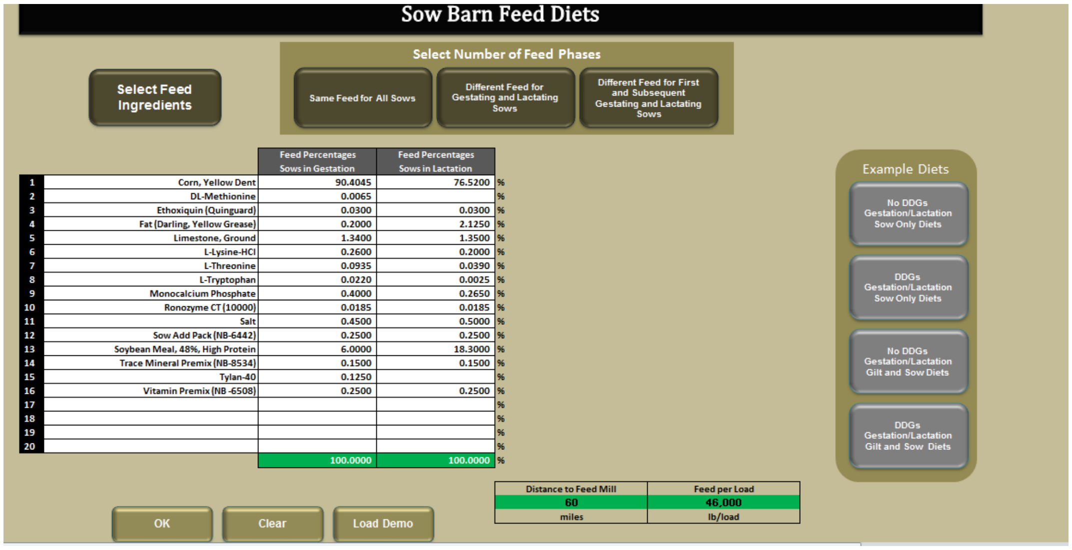
Water								
water consumed in cooling cells	86,310	gallons/year	0.24	gallons/pig/day	0	lb CO_{2e}/year	0.00E+00	lb CO_{2e}/lb water acquired
water consumed by pigs	1,050,256	gallons/year	3.07	gallons/pig/day	0	lb CO_{2e}/year	0.00E+00	lb CO_{2e}/lb water distributed
water for drip or sprinkler	85,611	gallons/year	0.24	gallons/pig/day	0	lb CO_{2e}/year	0.00E+00	lb CO_{2e}/lb water
water for barn washing	18,156	gallons/year	0.05	gallons/pig/day	0	lb CO_{2e}/year		
total water	######	gallons/year	3.60	gallons/pig/day	0	lb CO_{2e}/year		

Figure 3. Water Use and Footprint Output

2.7 Improvements to Feed Options

Version 1 allowed the user to enter up to 10 feeds for sow or grow barns along with up to 12 feed phases for the grow barn. Version 2 has the expanded capability of using up to 20 feed ingredients per phase and 2 phases for the sow barn and up to 20 phases for the grow barn. Additionally the choice of feeds was greatly expanded from 63 to 162 feeds representing protein, energy, amino acids, vitamins and minerals. These new feeds were taken from the NRC Swine Nutrition Guide (2012). Carbon footprints for each of the new feeds were gathered through a thorough review of the literature.

Feed can represent a substantial amount of emissions and day to day costs of a swine operation. Yet there is wide range of producer knowledge regarding diet composition and costs. Therefore feed entry has been restructured to accommodate both users who have good understanding of their feed mix composition/costs and those who do not. The model now includes “demo” diets for that can be loaded into any scenario. The sow barn has example diets with and without DDGs as well as differing diets for lactating and gestating animals. The grow barn currently includes two diets – with and without DDGs. (See examples in Figure 4 for Sow Barn and Grow Barn below). These diets were compiled by swine nutritionists at University of Arkansas and other land grant universities. In any of the barns, the user can choose to: 1) use the demo rations as provided, 2) modify those rations or 3) replace them completely with information from their own operation.



		Feed Percentages Sows in Gestation	Feed Percentages Sows in Lactation	
1	Corn, Yellow Dent	90.4045	76.5200	%
2	DL-Methionine	0.0065		%
3	Ethoxiquin (Quinguard)	0.0300	0.0300	%
4	Fat (Darling, Yellow Grease)	0.2000	2.1250	%
5	Limestone, Ground	1.3400	1.3500	%
6	L-Lysine-HCl	0.2600	0.2000	%
7	L-Threonine	0.0935	0.0390	%
8	L-Tryptophan	0.0220	0.0025	%
9	Monocalcium Phosphate	0.4000	0.2650	%
10	Ronozyme CT (10000)	0.0185	0.0185	%
11	Salt	0.4500	0.5000	%
12	Sow Add Pack (NB-6442)	0.2500	0.2500	%
13	Soybean Meal, 48%, High Protein	6.0000	18.3000	%
14	Trace Mineral Premix (NB-8534)	0.1500	0.1500	%
15	Tylan-40	0.1250		%
16	Vitamin Premix (NB -6508)	0.2500	0.2500	%
17				%
18				%
19				%
20				%
		100.0000	100.0000	%

	Phase:	1	2	3	4	5	6	7	8	
	Day Entering This Phase:	1	8	22	41	65	88	110	133	
	Day Leaving This Phase:	7	21	40	64	87	109	132	End	
1	Blood Plasma	3.5000	1.5000							%
2	Copper Sulfate			0.1000	0.1000	0.1000				%
3	Corn, Yellow Dent	37.9875	51.4510	60.9990	72.5050	78.2280	82.5055	84.9550	86.0810	%
4	DL-Methionine	0.0875	0.1200	0.1500	0.0410					%
5	Fat (Poultry)	2.5000	2.5000	2.5000						%
6	Fish Meal, Combined	6.5000	3.0000							%
7	Limestone, Ground	0.3750	0.6250	0.7250	0.7250	0.7500	0.7000	0.6750	0.6500	%
8	L-Lysine-HCl	0.1000	0.2450	0.3650	0.3030	0.2650	0.2300	0.2125	0.2050	%
9	L-Threonine		0.0590	0.1110	0.0760	0.0570	0.0395	0.0325	0.0390	%
10	Milk, Lactose	3.5000								%
11	Milk, Whey Powder	25.0000	12.0000							%
12	Monocalcium Phosphate	0.5000	0.7500	1.2000	1.1500	1.0500	1.0000	0.9500	0.9000	%
13	Neo-Terramycin 10-10	1.0000	1.0000	1.0000						%
14	Salt	0.2500	0.3500	0.5000	0.6000	0.5000	0.5000	0.5000	0.5000	%
15	Soybean Meal, 48%, High Protein	17.9500	25.7000	31.9500	24.2000	18.7500	14.7250	12.4500	11.4000	%
16	Trace Mineral Premix (NB-8534)	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	0.1250	0.1250	%
17	Vitamin Premix (NB -6508)	0.2500	0.2500	0.2500	0.1500	0.1500	0.1500	0.1000	0.1000	%
18	Zinc Oxide, 72% Zn	0.3500	0.3000							%
		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	%

Figure 4. Sow and Grow Barn Diet Screens

3. Project Tasks - Development of Economic Costing Capabilities

Work on the economic components of the model has focused on the collection of economic data and the development of economic algorithms to predict variable costs for the operation.

3.1 Economic Cost Database Development

In order to include economic capabilities into the model, economic cost data were needed associated with four general types of activities: 1) energy usage (utilities including water) to run fans, barn heating and cooling and pumps, 2) feed, 3) manure management and animal disposal. Over two dozen production budgets from across the US (see references) were gathered and reviewed to better understand the relative importance of these costs to total variable costs for the farm. The relative importance of these costs can range dramatically given the type of swine operation and the location and therefore collection of location-specific data can greatly improve the model's cost-estimation routines.

3.1.1 Utility Data

Goals for data collection included: 1) identifying comprehensive data sources so that costs would be consistently defined and calculated across the U.S. and 2) finding data as locally-specific as possible; that is, at a county or state-level, rather than a national level, so that default cost data in the model more accurately represent local conditions. Energy costs can represent 0.05% to 10% of overall variable costs of production.

Electricity, natural gas, propane, gas, diesel and water cost data have been collected for the most recent year data available. The Energy Information Administration (EIA) is the most comprehensive source for U.S. cost data on electricity, natural gas, propane, gas and diesel. Water cost data are from the USDA Census of Agriculture, Farm and Ranch Irrigation Survey. We communicated with employees of the EIA and USDA to ensure the collection of the right data.

For electricity costs, the model currently includes average retail prices (cents per kWh) to industrial customers for the year 2011. These data are presented on a county level, based on the EIA's (USEIA, 2012) data on average statewide retail prices for utilities and EIA's data on counties of operation for each utility. The cost entered into the model for a specific county is based on the weighted average of the statewide average retail price of each utility that operates in the specific county. The price entered is weighted by the volume of state-wide sales for utilities with operations in the county. In the future, we may validate this method by working closely with Public Utility Commissions (PUCs) in major swine production states to compare PUC and EIA-derived county-level cost estimates. Updates are only available once a year. Any future versions of the model will include data related to the most recent release.

Natural gas (USEIA, 2013a) and propane cost data (USEIA, 2013b) are also from the EIA and for the year 2012. Natural gas cost data are for the average price of natural gas delivered to industrial consumers in dollars per thousand cubic feet. Agricultural operations are defined as industrial customers. Natural gas data are available on a state-level and included in the model as state-level costs. Propane cost data represent average prices to other end users, which include agricultural users, in dollars per gallon. These data are by PADD District (Petroleum Administration for Defense District). There are 7 PADD districts in the U.S., with more locally specific data along the East Coast. Natural gas and propane data sets were recently updated (late June-early July) on line and will be incorporated into our model in the coming weeks.

Gasoline and diesel cost data (US EIA, 2013c) are the final types of energy cost day available through EIA. Data for the PADD Districts and nine states are available on a weekly basis. The model included information from the most complete data year (2012) as well as weekly estimates available through May 2013.

Water cost data from the USDA (2012) Farm and Ranch Irrigation Survey are from 2008, the most recent survey year. Here, we collected data for the costs of off-farm water. (Costs for pumping water are internally calculated in the model based on the energy source and well characteristics.)

The Farm and Ranch Irrigation Survey presents average costs for irrigation water from off-farm suppliers in dollars per acre foot. The Farm and Ranch Irrigation Survey publishes state-level results when possible. For five states, cost data are not available due to a limited number of farms and concerns over confidentiality. In this case, average costs for the Water Resource Region are used. (There are 20 Water Resource Regions in the U.S.) In the published survey results, data are not limited to livestock operations. We are currently exploring whether it is possible to limit cost data to livestock operations with the USDA.

3.1.2 Feed Costs

Feed costs can represent 20 to 70 percent of all variable costs for a swine operation. Prices for feed vary not only over time but also spatially. Therefore efforts were placed on developing feed ingredient cost databases that provided the most current and geographically relevant information for the user. It is important to note that no single database exists anywhere that includes the cost of all 162 ingredients for a common point in time across all country, state or regions. Therefore, great efforts were expended to collect cost information from dozens of sources including Chicago Board of Trade (2013) University of Missouri's (2013) weekly update on by-product feed pricing, Feedstuffs (2013), USDA Economic research Service (2013) Feed Grains Database as well as from various mills, manufacturers, academics and industry personnel. Costs for major ingredients (corn and soybeans for example) were widely available over time and across regions. However data for most of the minor ingredients were limited and dated. After consulting with the National Pork Board, version 2 of the Calculator offered national average as well as a minimum and maximum price (based on known January 2011 through April 2013 prices) were used in the model for each ingredient as the default prices.

3.1.3 Manure Handling and Animal Disposal Costs

Variable costs associated with manure handling represent only a very small portion (1-2%) of overall variable costs. These costs typically include labor, cleaning supplies, water and water delivery. Using national pork production budgets (see references) these costs were estimated on a per pig basis for inclusion in the model. Similarly, animal disposal costs are a small portion of the overall variable costs. Again, using recent pork production enterprise budgets, costs for the three types of disposal options national average costs of disposal on a per pig basis were estimated and used in the model. While this method may lead to small errors in actually calculation it eliminated the need to impose addition cost information needs (labor and cleaning supplies) on the user and because of its small overall economic importance, it is not expected to negatively impact overall cost calculations in the model.

3.2 Integration of Economic Algorithms in the Model

One of our greatest efforts has been the development and integration of economic algorithms into the Calculator. The economic algorithms allow a user to estimate the cost of day-to-day production inputs including energy, water, and feed. By combining this with emissions information in V2 of the Calculator users can now examine the relationships between emissions and costs and therefore potentially identify ways to reduce emissions at least cost. Over 200 economic algorithms were developed to calculate costs of utility and water use, feed rations, manure management and animal disposal. The calculator first runs the demographics model to estimate overall utility and feed usage as well as animal mortality. Then the economic algorithms use those values to calculate the costs associated with those activities.

New Economics user input screens were developed to allow the user to select the prices to use for each activity chosen for the scenario. The first tab displays the options available for energy and management activities (see Figure 5 below). Default prices (locally relevant where available) are automatically loaded for each activity. The user may use these default prices or customize the prices to those for his operation.

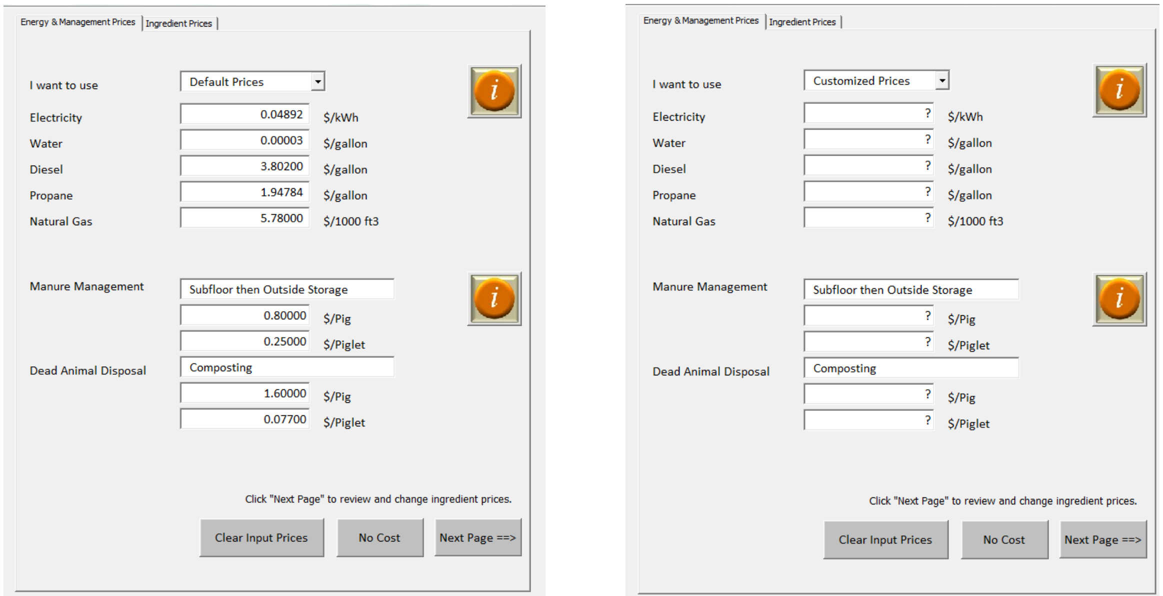
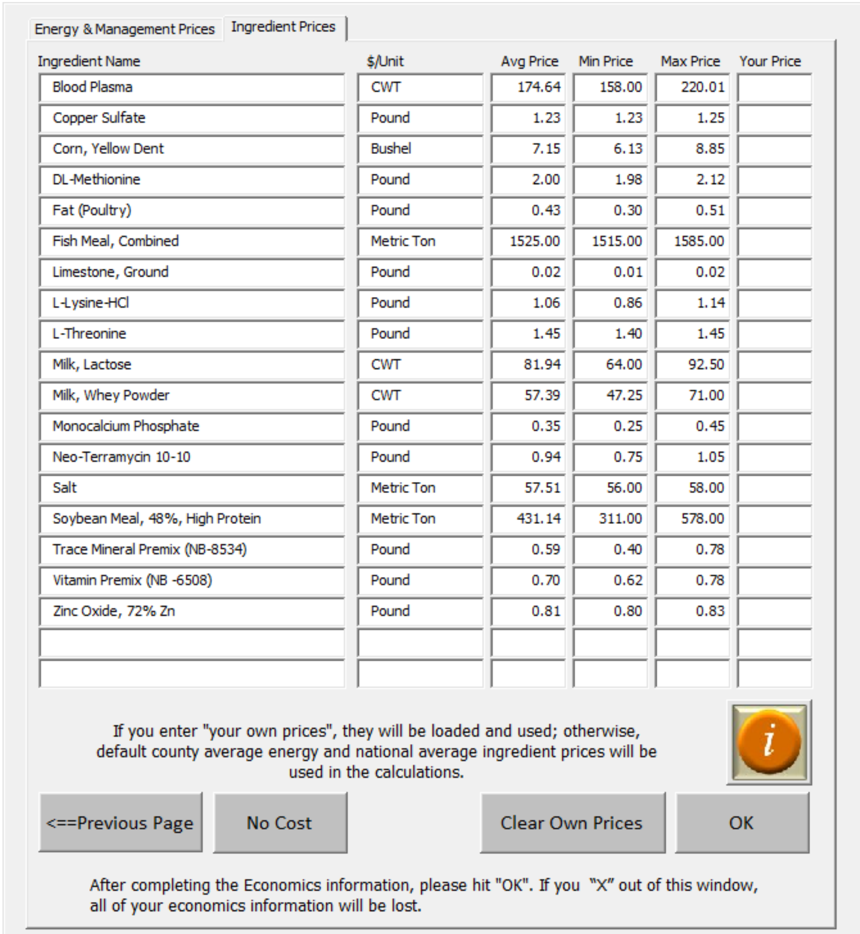


Figure 5. Energy and Management Price User Form

A similar procedure is followed for feed costs (see Figure 6 below). Once the feed ration has been specified in the model, the ingredient tab will automatically load the list of chosen ingredients and their national minimal, average and high prices. As before, the user can accept the default national average prices or change any/all ingredient prices to the listed minimum or maximum price, or a different price relevant to his operation. Because the costs of major feed ingredients – such as corn, soybean meal and DDGs can change substantially on a weekly basis, model users can choose to adopt feed ingredient prices by phase or adopt an average price over the full production period. Because of the static nature of the price database in the model, it is understood that these default prices are no longer timely by the release of the model. Therefore they are provided as a guide when estimating own prices.



Energy & Management Prices | Ingredient Prices

Ingredient Name	$/Unit	Avg Price	Min Price	Max Price	Your Price
Blood Plasma	CWT	174.64	158.00	220.01	
Copper Sulfate	Pound	1.23	1.23	1.25	
Corn, Yellow Dent	Bushel	7.15	6.13	8.85	
DL-Methionine	Pound	2.00	1.98	2.12	
Fat (Poultry)	Pound	0.43	0.30	0.51	
Fish Meal, Combined	Metric Ton	1525.00	1515.00	1585.00	
Limestone, Ground	Pound	0.02	0.01	0.02	
L-Lysine-HCl	Pound	1.06	0.86	1.14	
L-Threonine	Pound	1.45	1.40	1.45	
Milk, Lactose	CWT	81.94	64.00	92.50	
Milk, Whey Powder	CWT	57.39	47.25	71.00	
Monocalcium Phosphate	Pound	0.35	0.25	0.45	
Neo-Terramycin 10-10	Pound	0.94	0.75	1.05	
Salt	Metric Ton	57.51	56.00	58.00	
Soybean Meal, 48%, High Protein	Metric Ton	431.14	311.00	578.00	
Trace Mineral Premix (NB-8534)	Pound	0.59	0.40	0.78	
Vitamin Premix (NB -6508)	Pound	0.70	0.62	0.78	
Zinc Oxide, 72% Zn	Pound	0.81	0.80	0.83	

If you enter "your own prices", they will be loaded and used; otherwise, default county average energy and national average ingredient prices will be used in the calculations.

<==Previous Page | No Cost | Clear Own Prices | OK

After completing the Economics information, please hit "OK". If you "X" out of this window, all of your economics information will be lost.

Figure 6. Ingredient Price User Form

4. Project Tasks - Expanded User Friendly Model Output

Upon completion of the run, the program will take you to the first of many available output screens. For each of the barns, the output screens present a summary of the inputs entered and provides outputs related to demographics, emissions, feed, manure, utilities and costs. The following sections highlight the information provided on each of the screens.

4.1 Barn Summary

The *Barn Summary* screen (Figure 7) will appear first when the model run is complete.

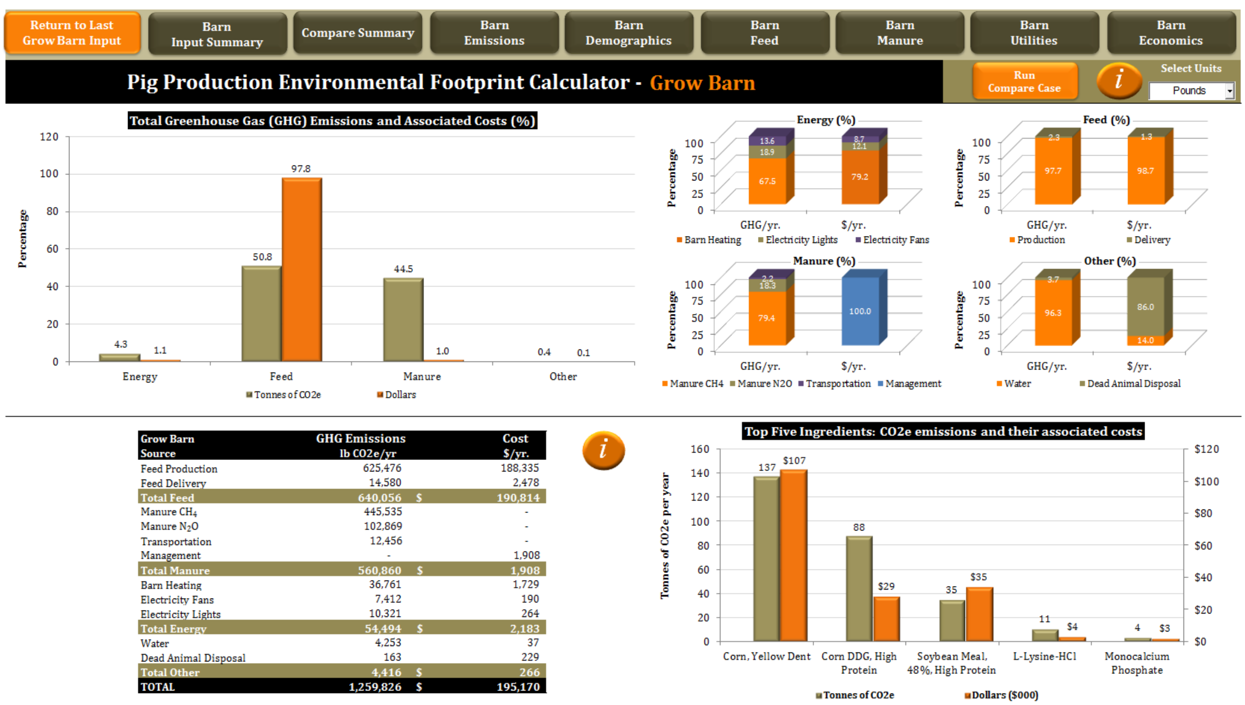


Figure 7. Barn Summary Screen

The *Barn Summary* screen highlights emissions and cost results for major barn activities. The results are presented in both tabular and graphical formats.

The Total Greenhouse Gas Emissions (%) and Associated Costs (%) graph on the top left summarizes the total percentage of emissions and costs for the four major classification categories: energy, feed, manure and all other activities. The chart on the right breaks down those emissions and costs into their individual components for each of those four categories. The table on the bottom left shows the actual numerical values for emissions (in pounds of CO_{2e} per year) and costs (in dollars per year).

Emissions or cost details related to any of the major classification areas may be viewed in either one of two ways. First users can access details by clicking on various components on the summary page. By holding the mouse over the Total Greenhouse Gas Emissions (%) and Associated Costs (%) graph chart and left clicking, a box will appear that allows you to choose to view details related to any of the emissions categories (Figure 8). Similarly clicking on the Top Five Ingredients graph and a navigation bar will direct the user to the Feed Emissions or Feed Ingredients Cost information (Figure 9). Otherwise, output details can be reached by navigating across screens using the output button pages at the top of the summary page.

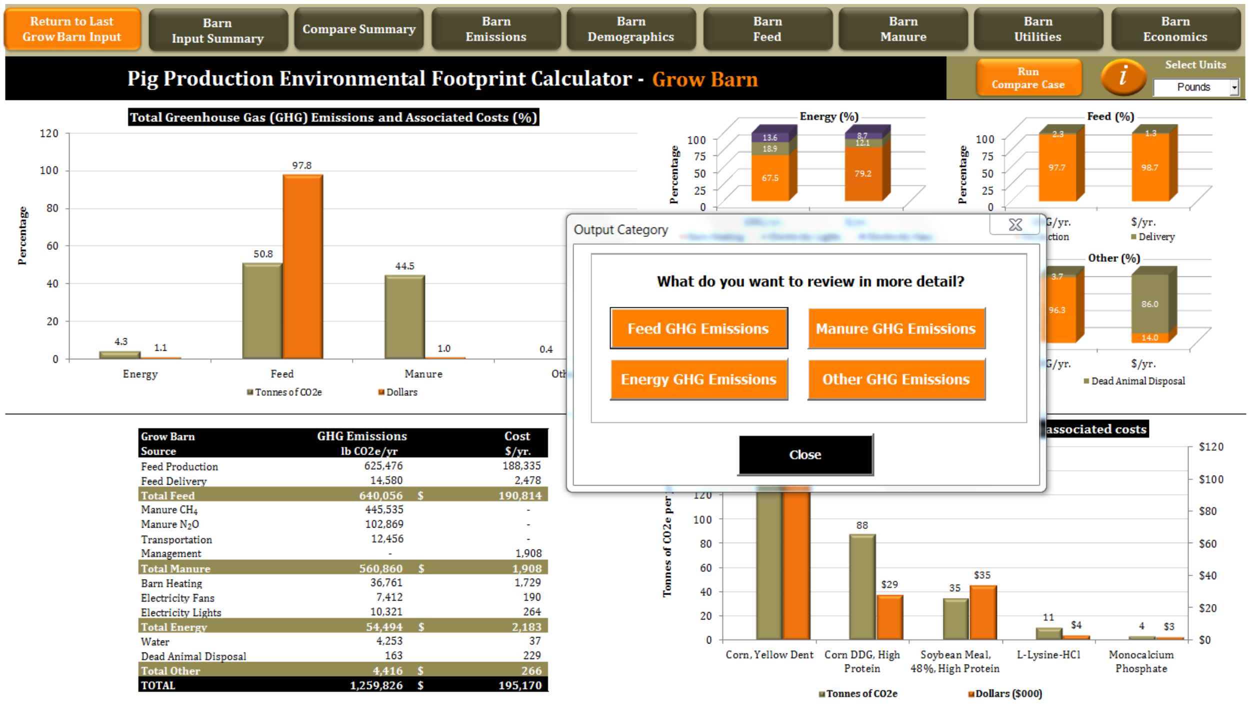


Figure 8. Viewing Detail By Left Click on Total Greenhouse Gas Emissions (%) and Associated Costs (%) graph

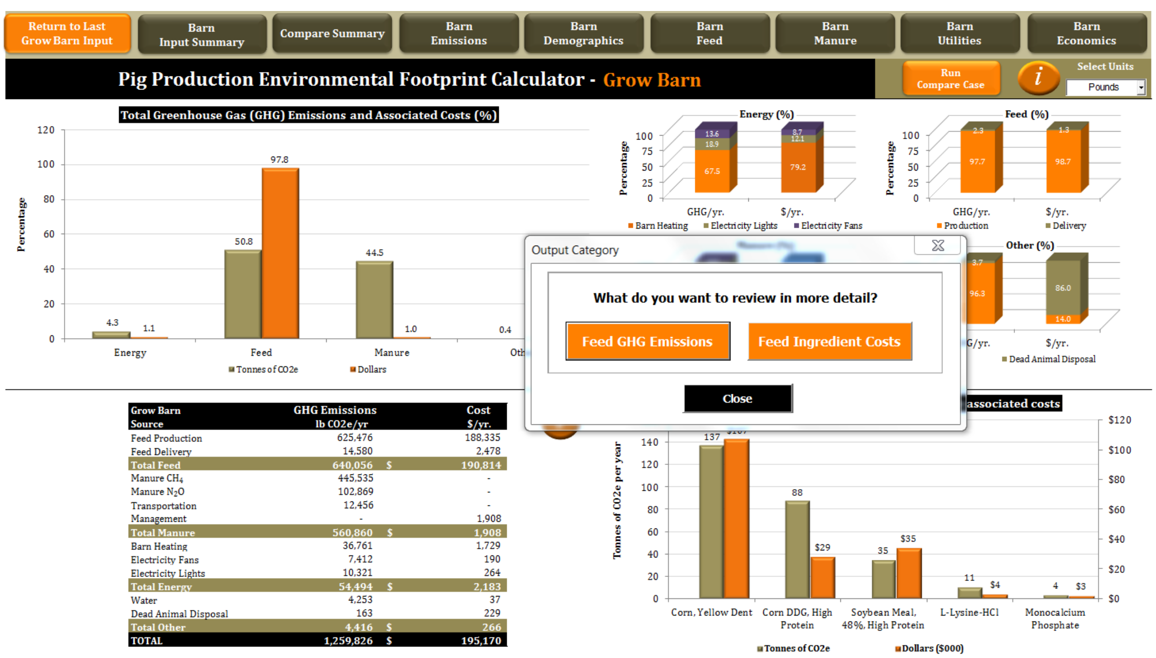


Figure 9. Viewing Detail By Left Click on Top Five Ingredients Graph

4.2 Barn Input Summary

The barn input summary page provides a complete list of all inputs that went into this case just as they were entered. There are no calculated results here. There can be over 500 individual inputs but many will be blank or zero for a given case and barn (Figure 10).

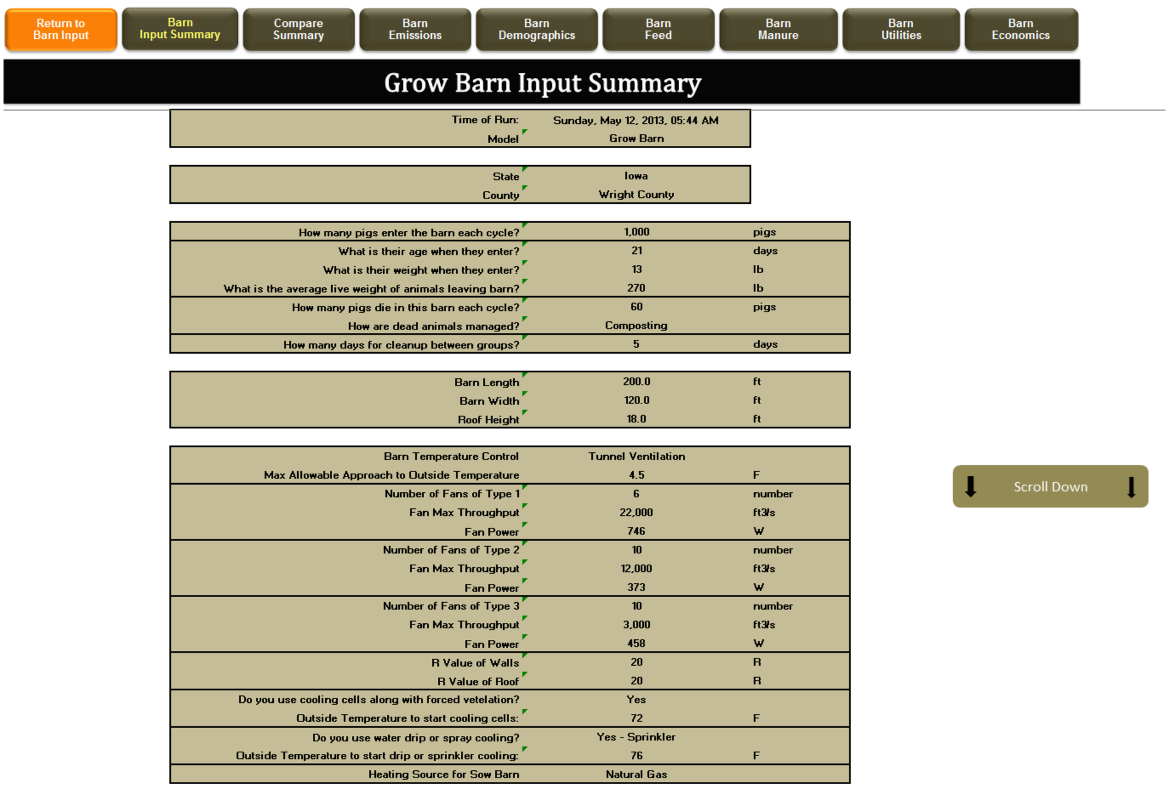
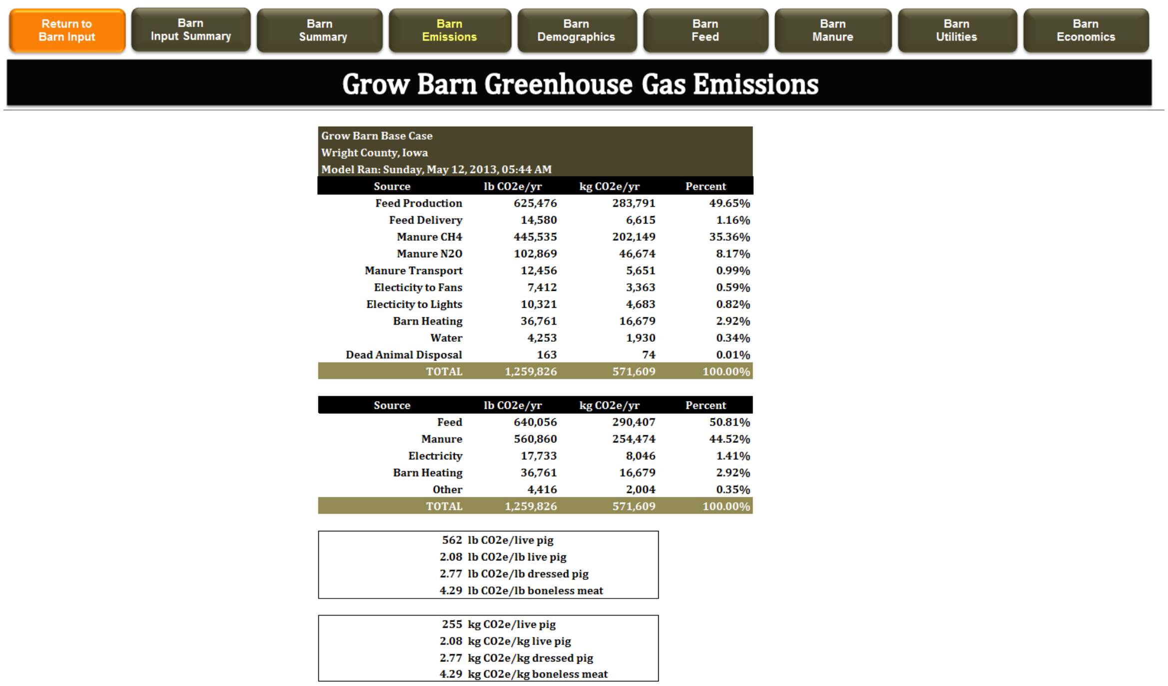


Figure 10. Barn Input Summary Screen

4.3 Barn Emissions

This screen gives the greenhouse gas emissions from the various parts of the pig barn and associated manure handling system, all expressed as CO_{2e}. The table shown below (Figure 11) lists the emissions by source, by category and by various definitions of finished animal. Results are given in both lb/yr and kg/yr of CO_{2e}. The calculator's inputs and outputs are written primarily in English units but kilograms are included here because it is by far the most common units for greenhouse gas emissions.



Grow Barn Base Case
Wright County, Iowa
Model Ran: Sunday, May 12, 2013, 05:44 AM

Source	lb CO2e/yr	kg CO2e/yr	Percent
Feed Production	625,476	283,791	49.65%
Feed Delivery	14,580	6,615	1.16%
Manure CH4	445,535	202,149	35.36%
Manure N2O	102,869	46,674	8.17%
Manure Transport	12,456	5,651	0.99%
Electicity to Fans	7,412	3,363	0.59%
Electicity to Lights	10,321	4,683	0.82%
Barn Heating	36,761	16,679	2.92%
Water	4,253	1,930	0.34%
Dead Animal Disposal	163	74	0.01%
TOTAL	1,259,826	571,609	100.00%

Source	lb CO2e/yr	kg CO2e/yr	Percent
Feed	640,056	290,407	50.81%
Manure	560,860	254,474	44.52%
Electricity	17,733	8,046	1.41%
Barn Heating	36,761	16,679	2.92%
Other	4,416	2,004	0.35%
TOTAL	1,259,826	571,609	100.00%

562	lb CO2e/live pig
2.08	lb CO2e/lb live pig
2.77	lb CO2e/lb dressed pig
4.29	lb CO2e/lb boneless meat

255	kg CO2e/live pig
2.08	kg CO2e/kg live pig
2.77	kg CO2e/kg dressed pig
4.29	kg CO2e/kg boneless meat

Figure 11. Barn Emissions Screen

The greenhouse gases considered in the calculator are CO_2, CH_4 and N_2O. These are emitted in various proportions by processes on the pig farm such as emission from manure, by upstream contributions such as fertilizer production for feed and by emissions that occur in both places such as the use of natural gas. For natural gas and other fossil fuels there is a direct emission from the farm where the fuels are combusted but there is also an upstream contribution corresponding to the energy needed to extract the fuel from nature, refine it, and transport it to the user. In all cases, the emissions of all three gases are lumped together as CO_{2e}, the amount of carbon dioxide equivalent to the emissions of all three of the gases. The conversions are:

$$1 \text{ lb } CO_2 = 1 \text{ lb } CO_{2e}, \text{ by definition}$$

$$1 \text{ lb } CH_4 = 25 \text{ lb } CO_{2e}$$

$$1 \text{ lb } N_2O = 298 \text{ lb } CO_{2e}$$

The following are some notes on emission sources for the various categories reported on this screen.

Feed Production - CO_2 emissions from fertilizer production, CH_4 emissions from field for crops such as rice.

Feed Delivery - CO_2 tailpipe and upstream emissions assuming wet feed is trucked in. You entered the weight per truckload and distance to the feed mill feed input form.

Manure Emissions - CH_4 and N_2O from the subfloor, lagoon, deep pit and/or outside storage.

Electricity - The emission factor in kg CO_{2e}/kW-hr of electricity delivered is known for the farm's specific location.

Barn Heating - The program performs a detailed heat balance on the barn every hour of the 10 years that it models taking into consideration the barn size, kind of walls, outside temperature/humidity, heat generated from pigs, contribution from venting fans and several others. When supplemental heating is needed, you select either natural gas or liquid propane and the calculator will use this to produce the required heat. CO_2 emissions for these fuels also include upstream burdens to the wellhead.

4.4 Barn Demographics

This screen shows the pig population demographics for the four types of barns (Figure 12). Various types of information are available depending on the barn type. Here are the results from the grow barn and sow barn demo cases as examples.

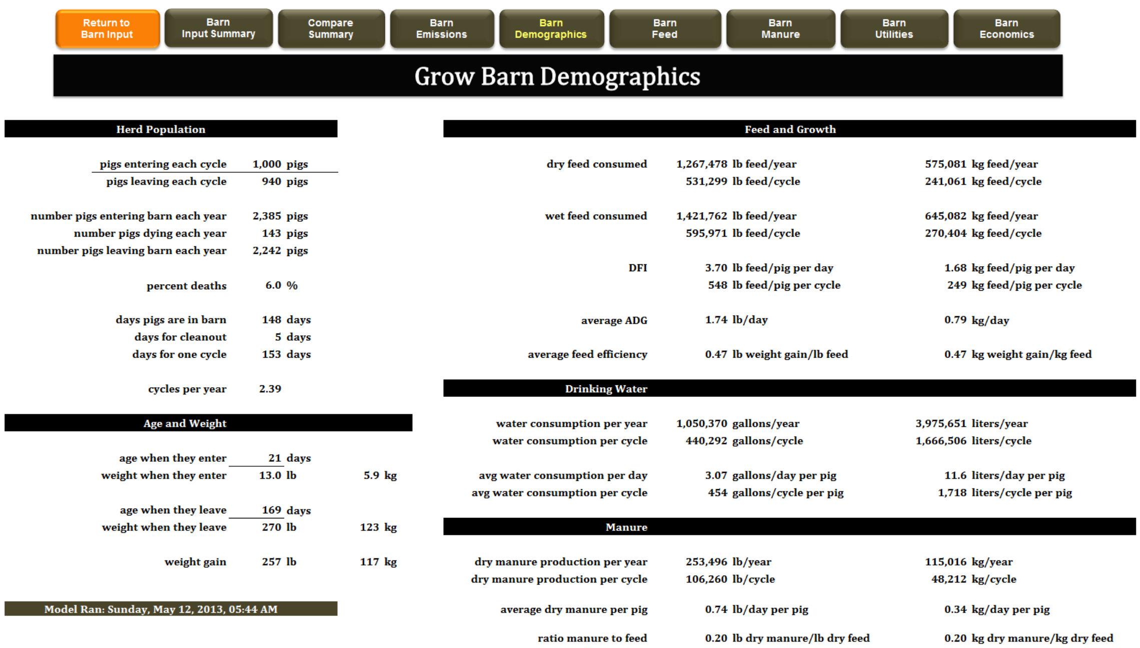
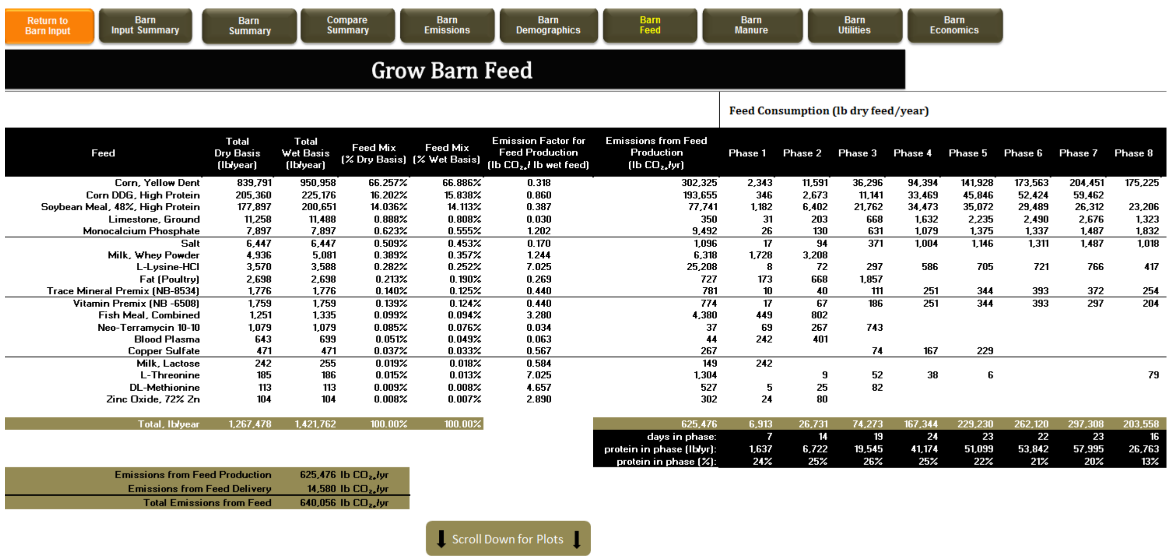


Figure 12. Barn Demographics Screen

Some of these data are a repeat of user inputs, such as the number of pigs entering each cycle into the grow barn, but most of them are calculated results, such as the number of pigs per year that pass through the grow barn. Since the calculator predicts how long a cycle will last, the yearly production is an output. In addition to herd statistics, summaries are given for average pig weight, age, amounts of various consumables including feed, drinking water and manure production.

4.5 Barn Feed

This screen highlights consumption and GHG emissions associated with the feed rations chosen in the scenario. The program calculates how much a pig eats each day based on its age, weight, gender, and reproductive status. Using all of this information, the program outputs the amount consumed for each feed (Figure 13). The model calculates the total amount of each feed per year on a dry and wet basis along with the emissions for growing and delivering that feed.



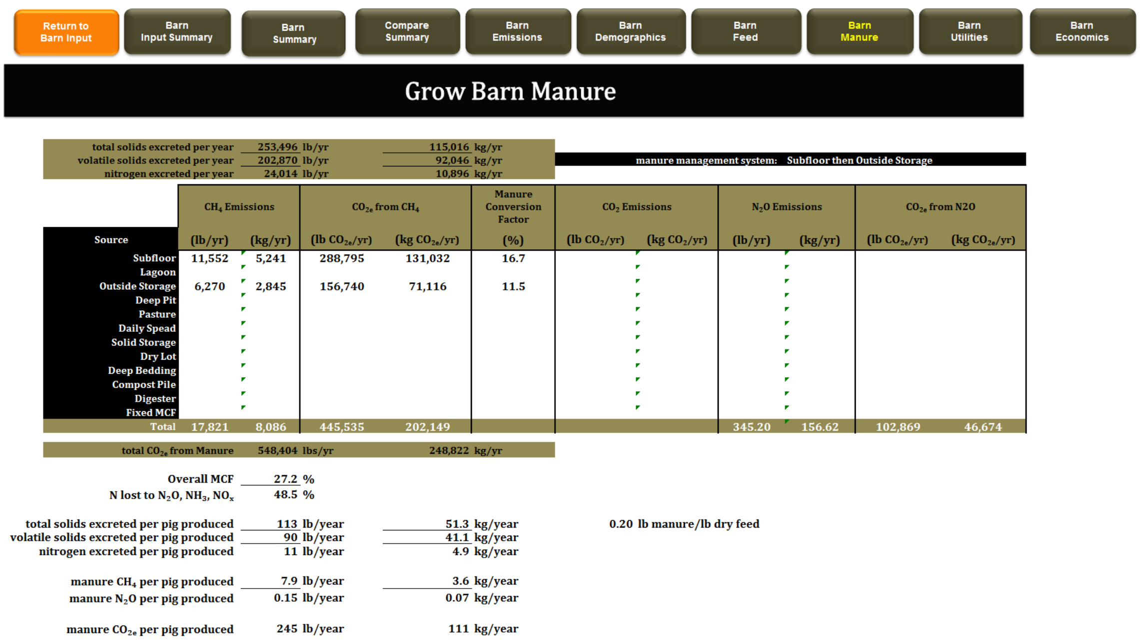
Feed	Total Dry Basis (lb/year)	Total Wet Basis (lb/year)	Feed Mix (% Dry Basis)	Feed Mix (% Wet Basis)	Emission Factor for Feed Production (lb CO_2/ lb wet feed)	Emissions from Feed Production (lb CO_2/yr)	Feed Consumption (lb dry feed/year) Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8
Corn, Yellow Dent	839,791	950,958	66.257%	66.886%	0.318	302,325	2,343	11,591	36,296	94,394	141,928	173,563	204,451	175,225
Corn DDG, High Protein	205,360	225,176	16.202%	15.838%	0.860	193,655	346	2,673	11,141	33,469	45,846	52,424	59,462	
Soybean Meal, 48%, High Protein	177,897	200,651	14.036%	14.113%	0.387	77,741	1,182	6,402	21,762	34,473	35,072	29,489	26,312	23,206
Limestone, Ground	11,258	11,488	0.888%	0.808%	0.030	350	31	203	668	1,632	2,235	2,490	2,676	1,323
Monocalcium Phosphate	7,897	7,897	0.623%	0.555%	1.202	9,492	26	130	631	1,079	1,375	1,337	1,487	1,832
Salt	6,447	6,447	0.509%	0.453%	0.170	1,096	17	94	371	1,004	1,146	1,311	1,487	1,018
Milk, Whey Powder	4,936	5,081	0.389%	0.357%	1.244	6,318	1,728	3,208						
L-Lysine-HCl	3,570	3,588	0.282%	0.252%	7.025	25,208	8	72	297	586	705	721	766	417
Fat (Poultry)	2,698	2,698	0.213%	0.190%	0.269	727	173	668	1,857					
Trace Mineral Premix (NB-8534)	1,776	1,776	0.140%	0.125%	0.440	781	10	40	111	251	344	393	372	254
Vitamin Premix (NB -6508)	1,759	1,759	0.139%	0.124%	0.440	774	17	67	186	251	344	393	297	204
Fish Meal, Combined	1,251	1,335	0.099%	0.094%	3.280	4,380	449	802						
Neo-Terramycin 10-10	1,079	1,079	0.085%	0.076%	0.034	37	69	267	743					
Blood Plasma	643	699	0.051%	0.049%	0.063	44	242	401						
Copper Sulfate	471	471	0.037%	0.033%	0.567	267			74	167	229			
Milk, Lactose	242	255	0.019%	0.018%	0.584	149	242							
L-Threonine	185	186	0.015%	0.013%	7.025	1,304		9	52	38	6			79
DL-Methionine	113	113	0.009%	0.008%	4.657	527	5	25	82					
Zinc Oxide, 72% Zn	104	104	0.008%	0.007%	2.890	302	24	80						
Total, lb/year	1,267,478	1,421,762	100.00%	100.00%		625,476	6,913	26,731	74,273	167,344	229,230	262,120	297,308	203,558
						days in phase:	7	14	19	24	23	22	23	16
						protein in phase (lb/yr):	1,637	6,722	19,545	41,174	51,099	53,842	57,995	26,763
						protein in phase (%):	24%	25%	26%	25%	22%	21%	20%	13%

Emissions from Feed Production	625,476 lb CO_2/yr
Emissions from Feed Delivery	14,580 lb CO_2/yr
Total Emissions from Feed	640,056 lb CO_2/yr

Figure 13. Barn Feed Screen

4.6 Manure Management

This output screen provides information related to total solids, volatile solids and nitrogen excreted per year as well as their related Methane (CH_4) and nitrous oxide (N_2O) emissions. Emissions are also expressed in their CO_2 emissions equivalents (CO_{2e}). Information is provided on a total basis and on a per pig basis (Figure 14).



total solids excreted per year	253,496	lb/yr	115,016	kg/yr
volatile solids excreted per year	202,870	lb/yr	92,046	kg/yr
nitrogen excreted per year	24,014	lb/yr	10,896	kg/yr

	CH_4 Emissions		CO_{2e} from CH_4		Manure Conversion Factor	CO_2 Emissions		N_2O Emissions		CO_{2e} from N2O	
Source	(lb/yr)	(kg/yr)	(lb CO_{2e}/yr)	(kg CO_{2e}/yr)	(%)	(lb CO_2/yr)	(kg CO_2/yr)	(lb/yr)	(kg/yr)	(lb CO_{2e}/yr)	(kg CO_{2e}/yr)
Subfloor	11,552	5,241	288,795	131,032	16.7						
Lagoon											
Outside Storage	6,270	2,845	156,740	71,116	11.5						
Deep Pit											
Pasture											
Daily Spead											
Solid Storage											
Dry Lot											
Deep Bedding											
Compost Pile											
Digester											
Fixed MCF											
Total	17,821	8,086	445,535	202,149				345.20	156.62	102,869	46,674

total CO_{2e} from Manure	548,404	lbs/yr	248,822	kg/yr
Overall MCF	27.2	%		
N lost to N_2O, NH_3, NO_x	48.5	%		
total solids excreted per pig produced	113	lb/year	51.3	kg/year
volatile solids excreted per pig produced	90	lb/year	41.1	kg/year
nitrogen excreted per pig produced	11	lb/year	4.9	kg/year
manure CH_4 per pig produced	7.9	lb/year	3.6	kg/year
manure N_2O per pig produced	0.15	lb/year	0.07	kg/year
manure CO_{2e} per pig produced	245	lb/year	111	kg/year

0.20 lb manure/lb dry feed

Figure 14. Barn Manure Output Screen

4.7 Barn Utilities

The program organizes utility and energy usage results on the **Barn Utilities** screen into five areas: fan operations, electricity, barn heat, diesel and water (Figure 15).

The fan operations table reports CFM values for the maximum ventilation rate with all fans running at full speed. It also presents the maximum amount of throughput needed for the size of the barn used in the scenario. Based on this information the program determines whether or not the barn has a sufficient number of fans and reports either “This barn has enough fans” or “This barn does not have enough fans.” If the barn does not have enough fans, you can click the **Return to Barn Input** and then click the **Heating and Cooling** button to adjust the number and/or maximum throughput of the fans and rerun the model.

Emissions are reported for electricity, natural gas, diesel and the energy needed to acquire and distribute water to the barn.

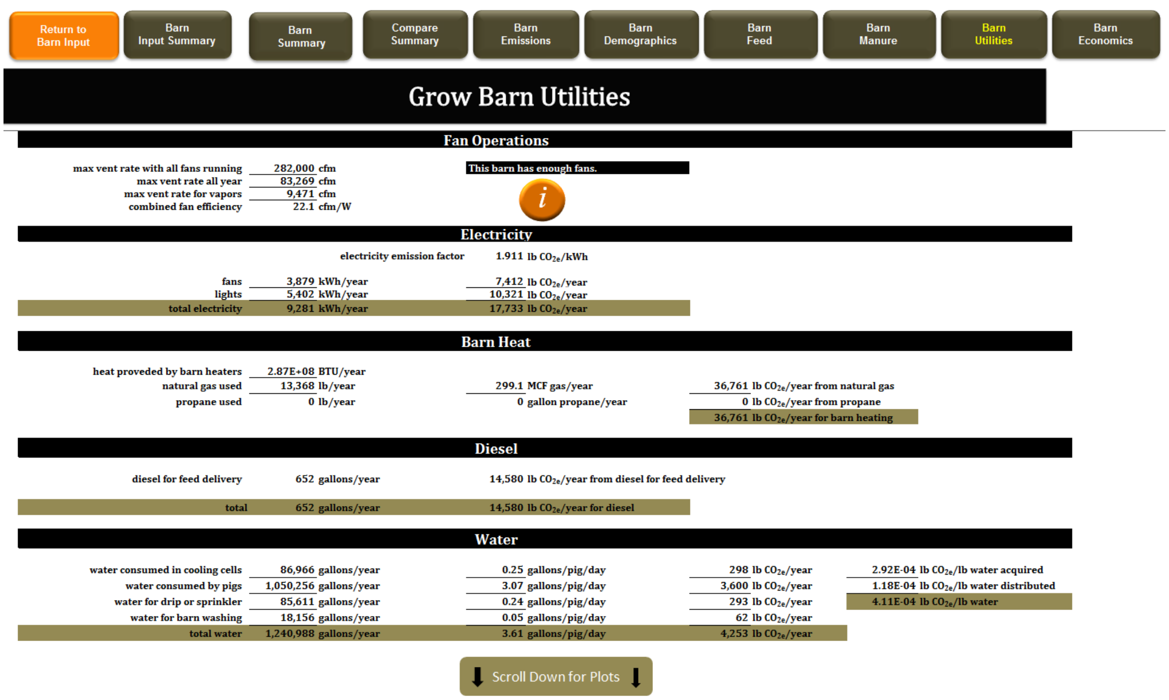


Figure 15. Barn Utilities Output Screen

4.8 Economic Analysis

The Barn Economics page (Figure 16) presents the cost results for fuel, utilities, manure management and dead animal disposal on one screen. Most costs are calculated based on the total units of those items used in the barn for the year.

As explained above, manure management costs include the costs of labor, energy and supplies needed to capture and move manure to the edge of the field. Dead animal disposal is made up primarily of energy costs for rendering and incinerating activities. Additional labor and supply costs are included in the composting estimates. Unlike other costs, manure management and dead animal disposal costs are reported on a per animal (pig or piglet) basis.

Return to Last Grow Barn Input | Barn Input Summary | Barn Summary | Barn Compare Summary | Barn Emissions | Barn Demographics | Barn Feed | Barn Manure | Barn Utilities

Economics - Grow Barn (Base Case)

TOTAL ENERGY USAGE COST ($/year)

Activity	Energy Source	Unit	Price/Unit	Usage	Total Cost
Barn heating	Natural Gas	MCF	$ 5.78000	299	$ 1,729
Barn heating	Propane	gallon	$ 1.94784	-	$ -
Fans	Electricity	kWh	$ 0.04892	3,879	$ 190
Feed delivery	Diesel	gallon	$ 3.80200	652	$ 2,478
Lights	Electricity	kWh	$ 0.04892	5,402	$ 264
Water consumed by pigs	Water	gallon	$ 0.00003	1,050,256	$ 32
Water consumed in cooling cells	Water	gallon	$ 0.00003	86,966	$ 3
Water for barn washing	Water	gallon	$ 0.00003	18,156	$ 1
Water for drip or sprinkler	Water	gallon	$ 0.00003	85,611	$ 3
					$ 4,698

FEED USAGE ($/year)

Ingredient	$/lb	lb	Total Cost
Corn, Yellow Dent	$ 0.13	839,791	$ 107,223
Corn DDG, High Protein	$ 0.14	205,360	$ 28,750
Soybean Meal, 48%, High Protein	$ 0.20	177,897	$ 34,790
Limestone, Ground	$ 0.02	11,258	$ 225
Monocalcium Phosphate	$ 0.35	7,897	$ 2,764
Salt	$ 0.03	6,447	$ 168
Milk, Whey Powder	$ 0.57	4,936	$ 2,833
L-Lysine-HCl	$ 1.06	3,570	$ 3,785
Fat (Poultry)	$ 0.43	2,698	$ 1,160
Trace Mineral Premix (NB-8534)	$ 0.59	1,776	$ 1,048
Vitamin Premix (NB -6508)	$ 0.70	1,759	$ 1,231
Fish Meal, Combined	$ 0.69	1,251	$ 866
Neo-Terramycin 10-10	$ 0.94	1,079	$ 1,014
Blood Plasma	$ 1.75	643	$ 1,123
Copper Sulfate	$ 1.23	471	$ 579
Milk, Lactose	$ 0.82	242	$ 198
L-Threonine	$ 1.45	185	$ 268
DL-Methionine	$ 2.00	113	$ 225
Zinc Oxide, 72% Zn	$ 0.81	104	$ 85
			$ 188,335

Scroll Down

MANURE COST ($/year)

Activity	$/pig	# of pigs	Total Cost
Manure Management	$ 0.80	2,385	$ 1,908
			$ 1,908

OTHER COST ($/year)

Activity	$/pig	# of pigs	Total Cost
Dead Animal Disposal	$ 1.60	143	$ 229
			$ 229

Figure 16. Economics Output Screen

5. Project Tasks – Developing Scenario Comparison Capabilities

The Calculator has a powerful feature for comparing the emissions and costs from two different model runs. Users can investigate numerous "what if" scenarios (e.g., what if DDGs are added to diets; what if prices for corn increase; what if allowable barn temperature fluctuations are reduced, etc.) and the algorithms calculate both the emissions and costs from each scenario. The extended output options provide summaries that highlight the sources and amounts of the differences in emissions and costs between the two scenarios. That is, this feature shows:

- the relationship between barn activities and emissions,
- the relationship between barn activities and costs, and
- how changing practices to reduce the emissions burdens can increase or decrease costs

This important and user friendly feature allows users to examine the expected impacts of proposed changes in their day to day barn activities before actual implementation.

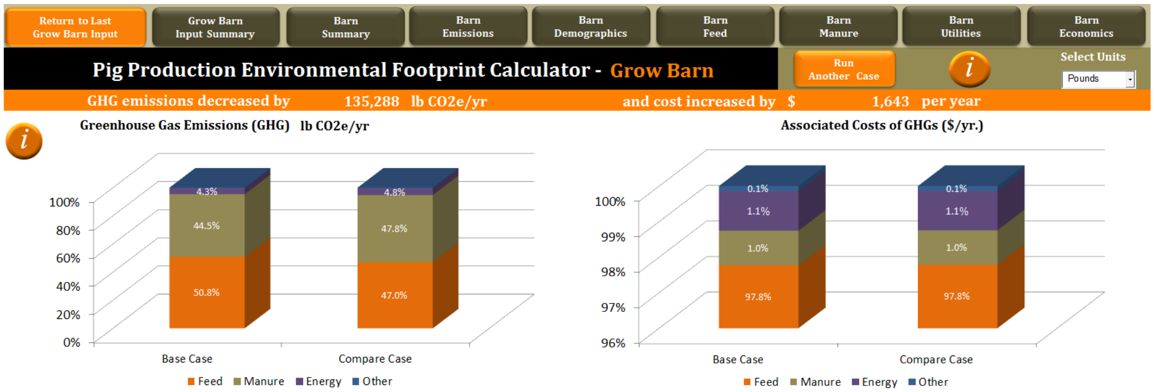
Additional new sets of algorithms and code were developed to save and compare model results from two different scenarios. This feature can be activated by running the model twice. The user can build and run the first barn scenario which the model calls the Base Case. Once the *Barn Summary* screen appears, the user must click the orange button to the right that is entitled Run Comparison Case. This takes the user to a new input screen for comparison cases (Figure 17).

Figure 17. Initial Input Screen for Comparison Case

The program automatically loads the inputs from the base case into the forms on this screen. To create the new scenario – the Comparison Case – users can change any one or more of the input values used in the Base Case.

At any point in this process a user can click on Load Base Case Inputs into Comparison Case. This will reset any changes made back to their values from the Base Case and the user can begin to build the Comparison Case again. Once satisfied with the changes, the user clicks the Run Comparison Case button.

This time, once the model has completed running, the program will automatically take you to a new output page that summarizes the emissions and costs results from the Base Case and the Comparison Case (Figure 18).



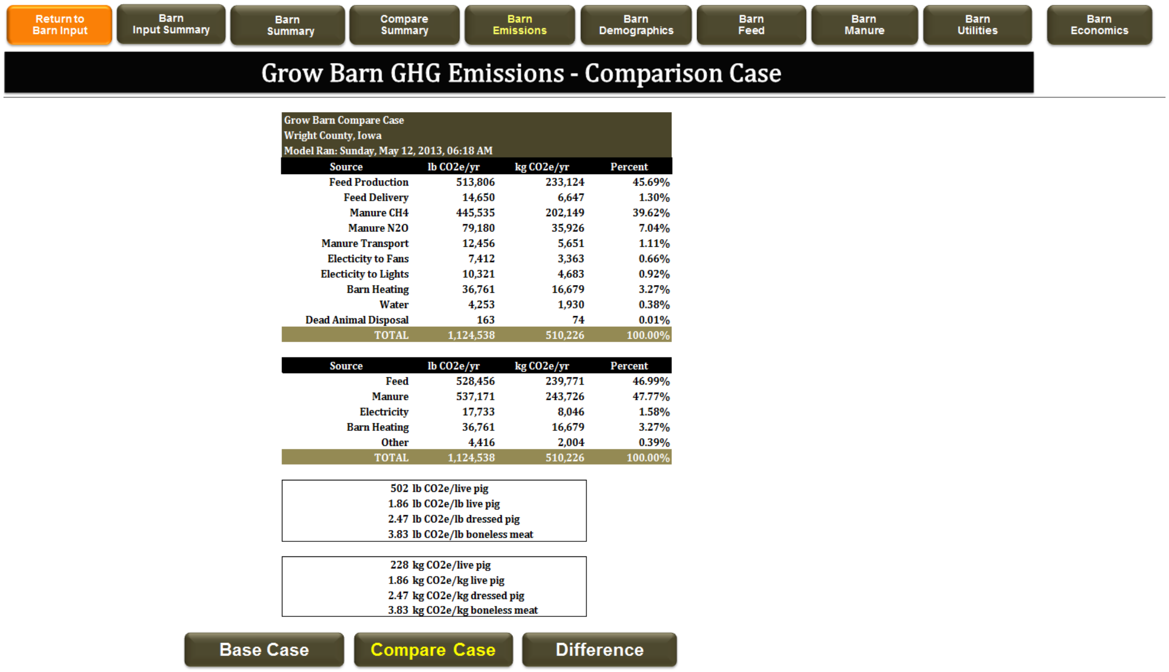
Grow Barn Source	Base Case lb CO2e/yr	Compare Case lb CO2e/yr	Difference lb CO2e/yr
Feed Production	625,476	513,806	(111,670)
Feed Delivery	14,580	14,650	70
Total Feed	**640,056**	**528,456**	**(111,600)**
Manure CH4	445,535	445,535	-
Manure N2O	102,869	79,180	(23,688)
Manure Transportation	12,456	12,456	-
Manure Management	-	-	-
Total Manure	**560,860**	**537,171**	**(23,688)**
Barn Heating	36,761	36,761	-
Electricity Fans	7,412	7,412	-
Electricity Lights	10,321	10,321	-
Total Energy	**54,494**	**54,494**	**-**
Water	4,253	4,253	-
Dead Animal Disposal	163	163	-
Other Total	**4,416**	**4,416**	**-**
Total	**1,259,826**	**1,124,538**	**(135,288)**

Grow Barn Source	Base Case $/yr.	Compare Case $/yr.	Difference $/yr.
Feed Production	188,335	189,967	1,631.4
Feed Delivery	2,478	2,490	11.9
Total Feed	**$ 190,814**	**$ 192,457**	**$ 1,643**
Manure CH4	-	-	-
Manure N2O	-	-	-
Manure Transportation	-	-	-
Manure Management	1,908	1,908	-
Total Manure	**$ 1,908**	**$ 1,908**	**$ -**
Barn Heating	1,729	1,729	-
Electricity Fans	190	190	-
Electricity Lights	264	264	-
Total Energy	**$ 2,183**	**$ 2,183**	**$ -**
Water	37	37	-
Dead Animal Disposal	229	229	-
Other Total	**$ 266**	**$ 266**	**$ -**
Total	**$ 195,170**	**$ 196,814**	**$ 1,643**

Figure 18. Comparison Summary Output Screen

Numbers in the difference column are colored green if the change represents a reduction in emissions and/or costs and colored red if the change represents an increase in emissions and/or costs. Messages above the graphs summarize the change in emissions and its impact on costs. If the emissions have decreased in the Comparison Case, this message will also show how much this reduction in emissions has cost (on a dollar per pound of CO_2e reduced basis) or saved compared to the Base Case. In the example above, total emissions fell by 135,288 lbs but costs increased by $28,740. Explained another way, it cost an additional $0.212 to reduce each pound of emissions from the Base Case to the Compare Case.

As before, the buttons along the top of the screen can be used to navigate to the various output pages to see results for the new comparison case. An additional example from the *Barn Emissions* (Figure 19) screen is shown below. By clicking the buttons at the bottom of each screen a user can to move between Base Case results, Comparison Case results and the Difference between the two for any output.



Grow Barn Compare Case
Wright County, Iowa
Model Ran: Sunday, May 12, 2013, 06:18 AM

Source	lb CO2e/yr	kg CO2e/yr	Percent
Feed Production	513,806	233,124	45.69%
Feed Delivery	14,650	6,647	1.30%
Manure CH4	445,535	202,149	39.62%
Manure N2O	79,180	35,926	7.04%
Manure Transport	12,456	5,651	1.11%
Electicity to Fans	7,412	3,363	0.66%
Electicity to Lights	10,321	4,683	0.92%
Barn Heating	36,761	16,679	3.27%
Water	4,253	1,930	0.38%
Dead Animal Disposal	163	74	0.01%
TOTAL	1,124,538	510,226	100.00%

Source	lb CO2e/yr	kg CO2e/yr	Percent
Feed	528,456	239,771	46.99%
Manure	537,171	243,726	47.77%
Electricity	17,733	8,046	1.58%
Barn Heating	36,761	16,679	3.27%
Other	4,416	2,004	0.39%
TOTAL	1,124,538	510,226	100.00%

502	lb CO2e/live pig
1.86	lb CO2e/lb live pig
2.47	lb CO2e/lb dressed pig
3.83	lb CO2e/lb boneless meat

228	kg CO2e/live pig
1.86	kg CO2e/kg live pig
2.47	kg CO2e/kg dressed pig
3.83	kg CO2e/kg boneless meat

Figure 19. Comparison Case Output for Emissions Screen

6. Project Tasks - Saving Output to PDF File

This program includes another new feature that allows the user to print all of results to one PDF file. PDF viewing software is needed to read the file once it is printed. This medium was chosen as free copies of the Adobe Reader is available from the Adobe website at http://get.adobe.com/reader

After viewing the output, users must return to the barn input screen by clicking the Return to Last Grow Barn Input button on the *Barn Summary* screen or Return to Barn Input from any of the output tabs and click on the Print Grow Barn Report button (Figure 20). The program will send a summary of major results to a PDF file that you can save and view on your computer.

Figure 20. Printing Grow Barn Report

Users are then given an option to suppress a screen flicker. If yes, is selected, it will seem as if the Excel program has disappeared temporarily. It will be hidden for approximately 10 to 15 seconds (depending on the speed of the computer) while the information for the PDF file is being captured from the output screens. If No, the user will be able to watch the print command move through the screens and capture information for the PDF file. The process takes less than a minute to complete. When finishing, the model prompts the user to name the report to be saved. After doing this, the report will be published and you will see an Adobe icon on the bottom of your screen. Click it to see the complete final report (Figure 21).

Figure 21. Viewing the Printed Output

7. Project Outreach and Education

Throughout the project we engaged in a number of activities to publicize our efforts and to solicit information from potential contributors. These activities included: 1) development of materials for the Pork Expo, 2) participating in NPB and producer meetings, 3) presentations at professional meetings, and 4) providing educational opportunities for undergraduate and graduate student researchers.

7.1 Pork Expo Materials

In conjunction with our related activities under the USDA NIFA pork grant, we contributed to the development of a pamphlet entitled *Integrated Resource Management Tool to Mitigate the Carbon Footprint of Swine Produced in the United States* that describes our NPB modeling activities and highlights the integration of DNDC, animal physiology and economic components into our model. (Please see pages 4 through 7 of Appendix A). This pamphlet was distributed widely during the Pork Expo in June 2012. Additional hard copies of the materials are available upon request.

7.2 Producer Meetings

Our team participated in the National Pork Board Environmental Section meetings throughout the project timeframe. These meetings provided the opportunity to report our efforts to date and to gain access to experts who have provided critical information related to the development of the economic modeling components.

Members of our team met with the Arkansas Pork Producers Association in person and by phone to update them on our project activities. Individuals associated with this association served as resources to our team for model testing and demonstration case information.

7.3 Presentations at Professional Meetings

Our team has actively promoted work associated with this project at numerous professional meetings. Between 2012 and 2013 our team made 4 oral presentations and 6 poster presentations. Five additional posters have been accepted for presentation in 2013.

Oral Presentations

2013

Apple, J.K., B. E. Bass, T. C. Tsai , C. V. Maxwell , J. W. S. Yancey , A. N. Young, M. D. Hanigan , R. Ulrich, J.S. Radcliffe, B. T. Richert, G. Thoma, J. S. Popp. 2013. Effects of amino acid supplementation of reduced crude protein (rcp) diets on performance and carcass composition of growing-finishing swine. Selected paper for the ASAS Midwestern Section / ADSA Midwestern Branch Annual Meeting. Des Moines, IA, March 11-13.

Thoma, G., R. Ulrich, J. Popp, M. Hanigan, B. Salas, P. Bandekar, S. Ghmir. 2013. Integrating Process Models with Life Cycle Costing Model for Quantification of Greenhouse Gas Emissions from US Swine Production. 2013. American Center for Life Cycle Assessment Annual Meeting, LCA XIII. October 3, Orlando Fl.

Ulrich, R., G. Thoma, J. Popp and G. Rodriguez. 2013. The US Swine Industries Carbon Footprint. Presentation at the ASAS-ADSA Meetings. Indianapolis, IN, July 8-12.

2012

Popp, J. G. Rodriguez, R. Ulrich, G.Vickery-Niederman, C. Maxwell, and G. Thoma. 2012. Integration of Cost Considerations Into the Live Swine Carbon Footprint Calculator. Selected paper presentation at the ASA, CSSA, SSSA International Annual Meetings, Cincinnati, OH Oct 21-24.

Poster Presentations

2014 (These were accepted during the project period)

Popp, J. H.G. Rodriguez, R. Ulrich, G. Thoma. 2014. Integrating a Life Cycle Costing Model into a Ghg Emissions Model for Swine Production. Poster presented at the NIFA Climate Change Project Directors Meeting, January 6-9, Gainesville, FL.

Rodriguez, H. G, J. Popp, R. Ulrich, G. Thoma, C. Maxwell and T.C. Tsai. 2014. Integrating a Life Cycle Costing Model into a GHG Emissions Model for Swine Production . Selected Poster at the Southern Sustainable Agriculture Working Group Annual Meeting, January16-18, Mobile, AL.

Thoma, G., M. Matlock, C. Maxwell, J. Popp, T. Costello –K. VanDevender, S. Sadaka, M. Hanigan, M. Ponder, C. Li, W. Salas, J.S. Radcliffe, B. Richert, R. Stowell and J. Heemstra. 2014. Integrated Resource Management Tool to Mitigate the Carbon Footprint of Swine Produced in the U.S. Poster presented at the NIFA Climate Change Project Directors Meeting, January 6-9, Gainesville, FL.

Thoma, G., R. Ulrich, C. Maxwell, J. Popp, P. Bandekar, H. Rodriguez, J. Burek, D. Kim, T. Tsai, H. Kim, M. Hanigan, C. Li and W. Salas. Compiling a Database of Carbon and Water Footprint and Nutrient Content of Animal Feed. Poster presented at the NIFA Climate Change Project Directors Meeting, January 6-9, Gainesville, FL.

Tsai, T.C., J. Popp, G. Thoma, R. Ulrich, C. V. Maxwell, M. Hanigan, B. Richert, and S. Radcliffe.2014. Effects of Amino Acid Supplementation with Reduced Dietary Crude Protein. Poster presented at the NIFA Climate Change Project Directors Meeting, January 6-9, Gainesville, FL.

2013

Popp, J. , H.G. Rodriguez, R. Ulrich , C. Li, W. Salas, and G. Thoma. 2013. Integrating biogeochemical process models with life cycle costing model for quantification of greenhouse gas emissions from US swine production. Selected poster for the Greenhouse Gas and Animal Agriculture Conference. Dublin Ireland, June 22-26.

Rodriguez, H.G., J. Popp, R. Ulrich, G. Vickery-Niederman and M. Black. 2013. Integrating a Life Cycle Costing Model Into a GHG Emissions Model for Swine Production. Selected

Poster for the Southern Agricultural Economics Association meetings Feb 3-5. Orlando, FL.

Tsai, T.C., B. E. Bass, M. D. Hanigan, J. K. Apple, R. Ulrich, J. S. Radcliffe, B. T. Richert, G. Thoma, J. S. Popp, and C. V. Maxwell.2013. Maximum Replacement of CP with Synthetic Amino Acids in Nursery Pigs. Selected Poster for the ASAS Midwestern Section / ADSA Midwestern Branch Annual Meeting. March 11-13, Des Moines, IA.

2012

Bass, B., T.C. Tsai, M. Hanigan, J. Apple, R. Ulrich; G. Thoma, J. Chewning, S. Radcliffe, J. Popp, and C. Maxwell. 2012. Effects of Amino Acid Supplementation of Reduced Crude Protein Diets in Growing/Finishing Pigs. Selected poster presentation at the ASA, CSSA, SSSA International Annual Meetings, Cincinnati, OH Oct 21-24.

Black, M., G. Rodriguez, J. Popp and R. Ulrich. 2012. Identifying Incentive Levels for Swine Producer Participation in Greenhouse Gas Emission Reduction. Poster Presentation at the Arkansas Water Resources Conference, Fayetteville, AR July 11-12.

Thoma, G, C. Maxwell, R. Ulrich, M. Matlock, J. Popp, K. VanDevender, S.Sadaka, T. Costello, S. Radcliffe, B. Richert, M. Hanigan, W. Salas, and C. Li. 2012. Integrated resource management tool to mitigate the carbon footprint of swine produced in the U.S. Invited Poster Presentation at the ASA, CSSA, SSSA International Annual Meetings, Cincinnati, OH Oct 21-24.

Webinars and Publications

Rick Ulrich presented “Greenhouse Gas Emission Study and Model for Swine Barn Operations” in a webinar for University of Nebraska Extension Service on June 15, 2012. About 50 viewers attended from industry, extension and production.

7.4 Educational Opportunities for Undergraduate and Graduate Student Researchers

The following individuals have participated in educational opportunities by working on this project.

<u>Ph.D. Students</u>

Jasmina Burek – Mechanical Engineering, University of Arkansas – collected most of the carbon footprint factors associated with the 162 feeds. Additionally she contributed to the collection of the feed ingredient characteristics needed for the inclusion of the NRC equations in the model.

Gina Vickery Neiderman – Environmental Dynamics, University of Arkansas - created the databases associated with the utility and water price data.

<u>M.S. Students</u>

Prathamesh Bandekar – Agricultural Engineering, University of Arkansas - Adapted and coded the NRC animal physiology equations for inclusion in the model.

Chelsea Coffman – Agricultural Economics, University of Arkansas – collected weekly/monthly/annual historical price information for most of the feed ingredients for inclusion in the feed price database.

Danielle Pribbernow – Agricultural Economics, University of Arkansas - collected the information related to the economics of manure management and developed the feed price database.

Undergraduate Students

Michael Black – Natural Resources, Cornell University – worked with our team as part of a Research Experience for Undergraduates program in summer 2012. He collected and organized all the pork production budgets to assess the relative (and realistic range of) costs associated with different day to day swine production activities.

Daniel Pumford - University of Arkansas Dept. Computer Science - worked with Dr. Ulrich on the transition from MatLab to C# and on interface development.

7.5 Educational Opportunities for the Undergraduate Classroom

In Fall 2013, lesson plans were developed for the Spring 2014 offering of University of Arkansas class AGEC 3413 Principles of Environmental Economics. University of Arkansas personnel worked closely with a small team of undergraduates to create the learning objectives for the Spring class. Approximately 75 students will learn to use the Pig Production Environmental Calculator. These students will develop and evaluate scenarios for their relative impacts on GHG emissions and costs. Honors students will summarize results of all scenarios and highlight those practices that show potential to reduce emissions at lowest costs.

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