RESEARCHREPORT
ENVIRONMENT

Title: Environmental Footprints for Regional Swine Production Systems Now and in the Future – A Demonstration Pilot Project **(NPB #18-042)**

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Industry Summary:

Environmental sustainability is a goal that increasingly influences decisions and actions at all levels of the pork industry, from individual producers to meat packers and retailers. Many analyses and tools can assess current production practices, and have the power to help identify and assess strategies for changing sustainability metrics in the future. The Pig Production Environmental Footprint Calculator (PPEFC; https://www.pork.org/environment/environmental-impact-pig-farming/) can use producer-supplied information to calculate farm-specific carbon, water and land footprints, and associated costs for their current production system. The calculator can also help producers explore strategies for changing their footprint - but only if producers use it.

This project explored if, and how, Extension and/or existing outreach networks can increase the adoption of the PPEFC through engagement, data gathering and strategizing. At the same time, aggregated footprints from cooperating producers provide a baseline for carbon and water footprints in the Midwest region, reflecting regional manure management and housing systems. We also explored strategies for changing the footprints.

We engaged with over 20 producers, and we generated footprints for 26 farms from Minnesota, Iowa, Nebraska and South Dakota. The majority of producer contacts were through networks of the project team. Based on survey responses by 10 producers, we found the producers we engaged with are aware of and engaged in protecting the environment, but the interest and specific knowledge about environmental footprints is highly variable. The producers' prior experience with environment footprints ranged from no experience to instances of producers who have looked into their operation's footprint in the past. We personally asked the majority of producers to participate, but the majority indicated "a desire to be able to address questions about pork production" was a major driver for participation.

Our footprint dataset included 4 breed-to-wean facilities, 11 wean-to-finish and 12 grow-finish facilities. For all farms, first we generated a set of footprints using a common set of corn-soybean based diet formulations for each stage of production. We created additional footprints for farms that supplied their farm diet formulations and/or production parameters like average daily gain (ADG) and feed conversion ratio (FCR).

Amongst the wean-finish barns using the common diet, the average (± standard deviation) carbon and water footprints were 2.40±0.09 lb CO2e per lb of pig and 26.0±0.9 gal H2O per lb of pig at the farmgate. The footprints both increased and decreased up to 5% with the producer-supplied production metrics. The average carbon footprint was 2.15±0.24 lb CO2e per lb of pig and the average water footprint was 23.5±2.7 gal H2O per lb of pig at the farmgate in the grow-finish phase. Producer supplied feed formulations and production metrics tended to increase carbon footprints up to 10%, but decrease water footprints by 20% for the grow-finish stage of production. For four breed-wean sites, the footprints were more variable, and comparison between sites depends greatly on the base unit. When the footprints are expressed per weaned pig produced, the carbon and water footprints ranged from 29 to 41 lb CO2e per weaned pig and 475 to 739 gal H2O per weaned pig for a common diet. The carbon footprints (per piglet) increased 33 to 64% when the farm-specific diet formulations replaced the common diet, but the water footprints decreased 19 to 31%. Generally, the carbon and water footprint contributions at the breed-to-wean stage are less than 25% of the overall footprints for a market pig.

The PPEFC footprints for the cooperating farms in the Midwest region that predominantly use deep pit manure storage show that feed production and manure storage represent over 95% of greenhouse gas emissions for wean-finish and grow-finish phases, and over 80% of emissions for breed-wean farms. Feed production is generally 90% of the water usage in a water footprint. However, building design and herd management contribute to efficient use of land, energy and water resources. Thus, we focused on describing and discussing four strategies for changing environmental footprints:

- Feed formulation;
- Manure management;
- Animal husbandry; and
- Record keeping.

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Keywords:

Environmental Footprint, Production efficiency, Energy utilization, Life-cycle analysis, Greenhouse gas, Carbon, Water

Scientific Abstract:

Environmental sustainability is a goal that increasingly influences decisions and actions at all levels of the pork industry, from individual producers to meat packers and retailers. Many analyses and tools can assess current production practices, and have the power to help identify and assess strategies for changing sustainability metrics in the future. This project explored if, and how, Extension and/or existing outreach networks can increase the adoption of the Pig Production Environmental Footprint Calculator (PPEFC) through engagement, data gathering and strategizing. At the same time, aggregated footprints from cooperating producers provide a baseline for carbon and water footprints in the Midwest region, reflecting regional manure management and housing systems. Our footprint dataset included 4 breed-to-wean facilities, 11 wean-to-finish and 12 grow-finish facilities. For all farms, first we generated a set of footprints using a common set of corn-soybean based diet formulations for each stage of production. We created additional footprints for farms that supplied their farm diet formulations and/or production parameters like average daily gain (ADG) and feed conversion ratio (FCR).

We engaged over 20 producers, and we generated footprints for 26 farms spanning Minnesota, Iowa, Nebraska and South Dakota. Based on survey responses by 10 producers, we found the producers we engaged with are aware of and engaged in protecting the environment, but the interest and specific knowledge about environmental footprints is highly variable. The producers' prior experience with environment footprints ranged from no experience to instances of producers who have looked into their operation's footprint in the past. We personally asked the majority of producers to participate, but the majority indicated 'a desire to be able to address questions about pork production' was a major driver for participation.

Amongst the wean-finish barns using the common diet, the average (± standard deviation) carbon and water footprints were 2.40±0.09 lb CO2e per pound of pig and 26.0±0.9 gal H2O per pound of pig at the farmgate. The footprints both increased and decreased up to 5% with the producer-supplied production metrics. The average carbon footprint was 2.15±0.24 lb CO2e per pound of pig and the average water footprint was 23.5±2.7 gal H2O per pound of pig at the farmgate in the grow-finish phase. Producer supplied feed formulations and production metrics tended to increase carbon footprints up to 10%, but decrease water footprints by 20%. For four breed-wean sites, the footprints were more variable, and comparison between sites depends greatly on the base unit. When the footprints are expressed per weaned pig produced, the carbon and water footprints ranged from 29 to 41 lb CO2e per weaned pig and 475 to 739 gal H2O per weaned pig for a common diet. The carbon footprints (per piglet) increased 33 to 64% when the farm-specific diet formulations replaced the common diet, but the water footprints decreased 19 to 31%.

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Introduction:

A footprint is a physical representation of one's impact on the surroundings. In an environmental context, a footprint denotes the impact of someone or something on the environment, generally based upon the natural resources used or contaminants emitted by the routine activities of that someone or something. A carbon footprint represents the amount of greenhouse gases generated during production in units of carbon dioxide, while the water footprint is the amount of water used. The most commonly employed procedures, processes and tools to develop these footprints are collectively referred to as life-cycle analysis (LCA).

The scope of the footprint - defined by the boundaries of the LCA - is critical for both understanding and reacting to a footprint. In the swine industry, we often look at the resources used to take a pig from birth to market, or through different production stages (breed-to-wean, nursery, grow-to-finish). Some inputs to footprints for a swine operation are obvious: pigs eat feed and drink water. However, energy is required to cultivate and move crops from fields to the feedmill and into the production barn. Land and water are also crucial for crop production, with irrigation sometimes supplementing the natural rainfall. In the swine production system, energy and water are generally required for ventilation, heating, and cooling systems to maintain a comfortable environment in the barn. This scope - that includes resources used for and emissions from providing feed, operating production facilities, and managing animals and manure to support a pig through its growth - is referred to as "cradle-to-farmgate", and illustrated in Figure 1. When a footprint also includes pork processing, delivery to stores, and preparation by consumers, the scope is called "cradle-to-plate".

How footprints are expressed is very important to their interpretation and communication. Footprints should generally be expressed as "___ units of ___ per unit of ___". Simply knowing that one operation uses twice as much water as another may have some value for comparing relative demand on the local water supply, but has little or no value in evaluating or comparing facilities and practices in place on the two farms. One way of unitizing footprints is to express them on a production unit or "per pig" basis. Expressing the carbon footprints of breed-to-wean facilities, for example, in tons of CO2e (carbon-dioxide equivalent) per sow may be appropriate and useful for making cursory comparisons among those facilities. The utility of footprints is usually improved, though, by unitizing on the basis of final product. For example, expressing the carbon footprints of breed-to-wean facilities in tons of CO2e per weaned piglet would better highlight efficiencies or deficiencies in the systems. While weaned pigs may be the practical final product of a breed-to-wean operation, the final product of swine production is finished market pigs, and even more appropriately, pounds of live-weight hogs. As an illustration, by unitizing the greenhouse gas emissions assigned to breed-to-wean facilities on the basis of cwt of hogs marketed annually, an operation could make a more "apples-to-apples" assessment of the role of the breed-to-wean operation in the farm's overall carbon footprint. This also allows for better assessments to be made across time as market weights, production systems and efficiencies change (e.g. 1950's hog vs. modern market hog).

The National Pork Board Strategic Plan (2019) strives to reduce the region- and production-weighted national average carbon and water footprints by 5% between 2014 and 2020. The strategic plan also calls for producer engagement in reporting these metrics (NPB, 2019). How will the industry, as a whole, meet the goals of the strategic plan regarding environmental sustainability? Are incremental or large changes to individual or regional operating systems necessary? What prompts producer engagement in this process?

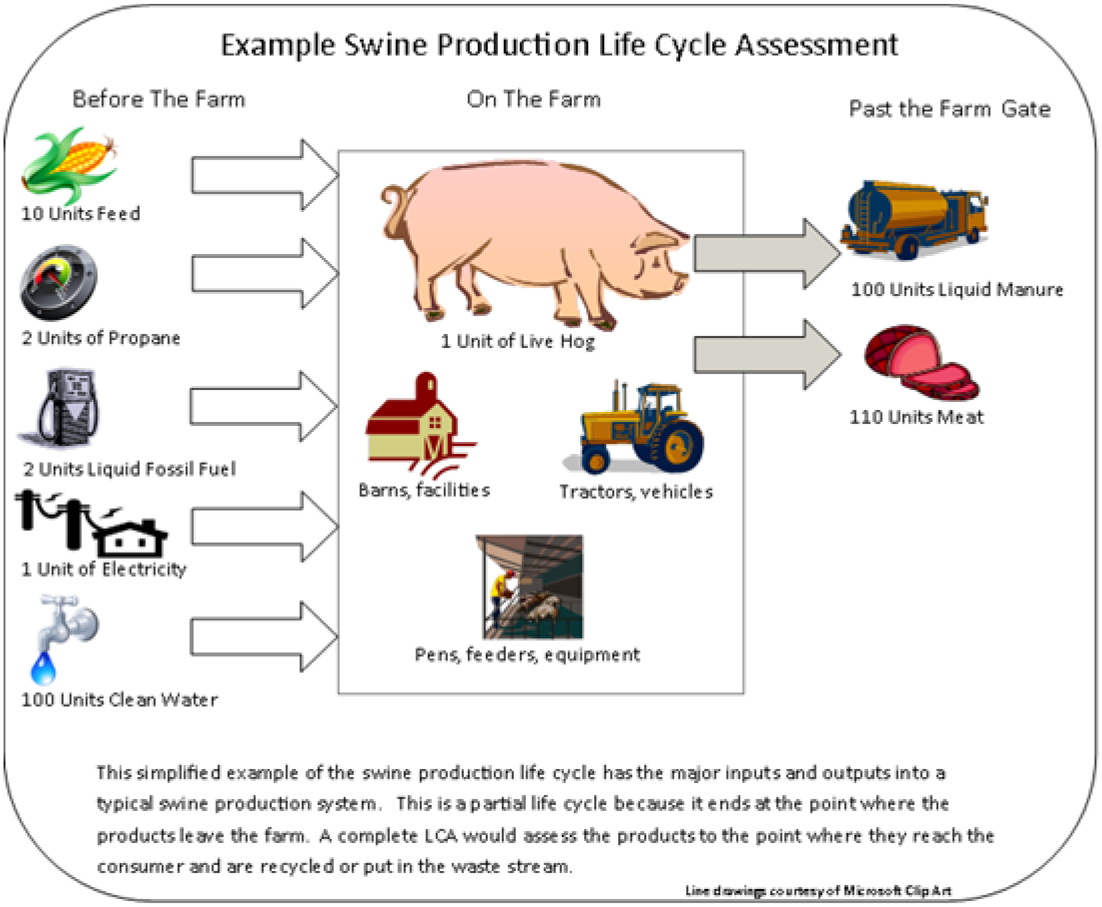


Figure 1 Illustrated example of the components and relative contributions to a cradle-to-farmgate footprint using life cycle assessment.

This project engaged local producers in discussions and actions related to sustainability and associated metrics. The farm-specific and summarized regional data provide baselines to investigate farm-specific and regional opportunities for change to the sustainability metrics. The sustainability metrics, in the form of environmental footprints, also provide producers with information to use in community discussions about environment and sustainability. The hypothesis of the project herein is that Extension and/or existing outreach networks can increase the adoption of technology through strategic programming, data gathering and strategizing.

Objectives:

The specific objectives were to:

1. Engage 65 producers in Environmental Footprint calculations of current production practices.

2. Measure the change in knowledge, interest and trust in environmental sustainability and related metrics following engagement with local educators.

3. Identify and evaluate strategies that have potential to help local producers reach sustainability metric goals using Life Cycle Analysis.

Materials & Methods:

Participant Engagement

Our approach to participant engagement was to first test a public call for engagement for one month, followed by direct contacts. The public call for participants was through newsletters, social media and pamphlets. We engaged the majority of participants through our personal networks of contacts in the swine industry. In some cases, when addressing extension questions, team members extended an invite to participate in this project. National Pork Board staff also relayed some participants to the project.

The first contact was typically in person, by phone or a short email message to gauge general interest. If general interest was there, additional follow-up provided more information on data needs and the general process. Some producers provided data for multiple sites. Some producers expressed a willingness to participate but subsequent calls to them have not panned out. Thus, the number of engaged producers and number of footprints are not the same. We assigned each farm a unique identifier and producer names, addresses or other identifiable information was left off the data collection and report forms. We maintained the list of cooperating producers, their contact information and their identifier in a password-protected file. The University of Minnesota Institutional Review Board determined the project activities were not research involving human subjects.

When data were collected via email, we used the short-form questionnaire available at Pork.org. When collecting information in person, we used a modified version that included survey questions (described in Documenting Change in Knowledge and Trust).

Our approach for each site was to use the PPEFC and:

- Generate a footprint using a common diet for the phase of production (a corn-soybean diet based on the National Swine Nutrition Guide) and model-calculated production metrics (i.e. average daily gain and feed to gain);
- Generate a footprint using the farm-specific diet (if provided) and model-calculated production metrics; and
- Generate a footprint using farm-specific diet (if provided) and producer-supplied production metrics (if provided).

The common diets are in Appendix A

It is important to note that the project team did not create the PPEFC. Project team members have variable levels of understanding how the PPEFC uses each input factor to produce the various footprints. We do not know the whole suite of calculations behind the user interface. On occasion, we consulted the program developers, particularly when experiencing user errors. Thus, we can only report what the PPEFC estimates, but not the entire “why”.

We shared the short and long summary footprint reports generated by the PPEFC with the cooperating producers.

We aggregated the simulation results from all sites for wean-to-finish (WF), grow-to-finish (GF) and breed-to-wean (BW) sites to provide a regional range of footprints. For each stage, we also aggregated the distribution of carbon and water footprint components.

Documenting Change in Knowledge and Trust

We developed surveys for pre- and post-footprint exercise with the producers. The pre-survey questions were delivered verbally to the participant and answers recorded by the team member. The pre-survey gathered the following types of data:

- Reasons for participating in project;
- Experience with footprints;
- Knowledge of footprint components and industry averages; and
- Self-evaluation of operation's sustainability.

The post-survey will be delivered electronically to participants. We have delayed deploying the post-survey until the aggregated footprints are shared with the producers. The post-survey will gather the following types of data:

- Impressions of footprint results;
- Intentions for change in operation; and
- Trust in the footprint results.

Identifying and Evaluating Strategies to Change Footprints

Through working with producers, we noted strategies and actions that changed environmental footprints within the range of farms we worked with. Ultimately, we chose to focus on documenting the influence of four strategies for changing the environmental footprint of Midwest swine operations. Note, while the overall goal is to improve sustainability, some strategies had positive effects on one footprint (i.e. carbon) while negatively influencing another footprint (water); thus, we focus on demonstrating how the strategies change footprints to aid producers in their decision-making.

The strategies relate to four primary areas: altered feed formulations, manure management; animal environment and husbandry; and record keeping. We investigated the influence of the four strategies using the PPEFC and the West Central Research and Outreach Center (WCROC) LCA model (Tallaksen, Johnston, Sharpe, Reese, & Buchanan, 2019) where appropriate. For the various strategies, we demonstrated how and why the footprint calculations change.

Results:

Objective 1: Engage producers in footprint calculations

The public call for participants through newsletters, social media and pamphlets generated only two responses. National Pork Board staff forwarded three participants. All other contacts resulted from the networks of project members. There were two instances of producers not willing to participate. Perceived data security and environmental regulation repercussions on the part of the producers appear to be the reason.

Ultimately, we engaged over 20 producers. The producers were from Minnesota, Iowa, Nebraska and South Dakota. We generated footprints for 26 farms. Our dataset includes 4 breed-to-wean facilities, 11 wean-to-finish and 13 grow-finish facilities. We created multiple footprints for farms that supplied specific farm diet formulations and/or production parameters like average daily gain (ADG) and feed conversion ratio (FCR).

Footprint Summary

Figure 2 shows the carbon and water footprints for the participating wean-finish and grow-finish farms using a common corn and soybean based diet and the calculator-estimated production, and with the farm diet and producer-supplied production numbers where available. Table 1 summarizes the average and range of footprints.

Amongst the wean-finish barns using the common diet, the average (±standard deviation) carbon and water footprints were 2.40±0.09 lb CO2e per lb pig and 26.0±0.9 gal H2O per lb pig. The footprints both increased and decreased up to 5% with the producer-supplied production metrics. The average footprints for grow-finish barns were slightly lower than the wean-finish barns, as expected, because pigs consume fewer resources for the shorter growth span within the grow-finish phase of production. The average carbon footprint was 2.15±0.24 lb CO2e per lb pig and the average water footprint was 23.5±2.7 gal H2O per lb pig in the grow-finish phase. Carbon footprints tended to increase up to 10% using farm diets and both increased and decreased with producer-supplied production metrics. The water footprints decreased up to 18% with the farm diets.

We generated footprints for four breed-wean sites, and three sites provided farm-specific diets (Figure 3). The project personnel and producers expressed some confusion over the entry of data for gestation, sow and farrowing barns. Therefore, our confidence in these footprints is lower than the wean-finish and grow-finish sites based on the places where entry errors were possible. Through trial and error, we discovered the calculated annual number of piglets produced was a gauge for how well the pig flow was entered in the calculator. The pig flow and piglets produced per year were very dependent on the number of days sows were in the farrowing rooms prior to farrowing, the days until weaning, and the days post-weaning before sows were moved back to the breeding barn. We also felt the footprint results required additional interpretation than the footprints per live pig and per pound of live pig readily available on the footprint summary. The footprint summary reports express the footprints per live pig or per pound of live pig based on the culled sows. When used in a cumulative footprint for a pig from birth to market, an expression of the footprint per piglet may prove more useful.

Carbon footprints for sow farms are more variable. The addition of a gilt development unit increases the footprint for an individual farm, and feed formulation and manure storage can also greatly influence the results. Farms BW1, BW2 and BW3 had deep-pit manure storage in the gestation barns; BW4 used outdoor manure storage. The carbon footprints (per weaned pig) for Farms A, B and C (Figure 3) increased 33 to 64% when the farm-specific diet was used instead of the common diet, but the water footprints decreased 19 to 31%.

Between farms, carbon and water footprints are not directly indicative of each other. When we compare two farms' footprints, a lower carbon footprint for one farm relative to another does not always mean the water footprint will be lower.

To compare the average regional footprints to the 2104 national baseline of 2.87 lb carbon dioxide equivalent and 18.66 gal H2O per lb of live-pig at the farmgate (NPB, 2019), the numbers for the different phases of production need to be combined appropriately. To estimate cradle-to-farmgate footprints from this project's data, the footprints for BW and WF expressed on a per weaned pig and per pig at the farmgate can be summed. Note, this dataset and approach does not account for culled sows in addition to market pigs at the farmgate, and has limited information on resource use for gilt development. Using the common diet footprints in Table 1, the cradle-to-gate carbon and water footprints are approximately 2.38 lb of CO2e and 26.7 gal H2O per lb of live-pig at the farmgate, respectively. Figure 4 demonstrates the relatively small impact of the breed-to-wean production stage compared to the wean-to-finish stage for the carbon footprint. Using a different LCA model, the relative contributions by the different production stages for a research farm are also shown.

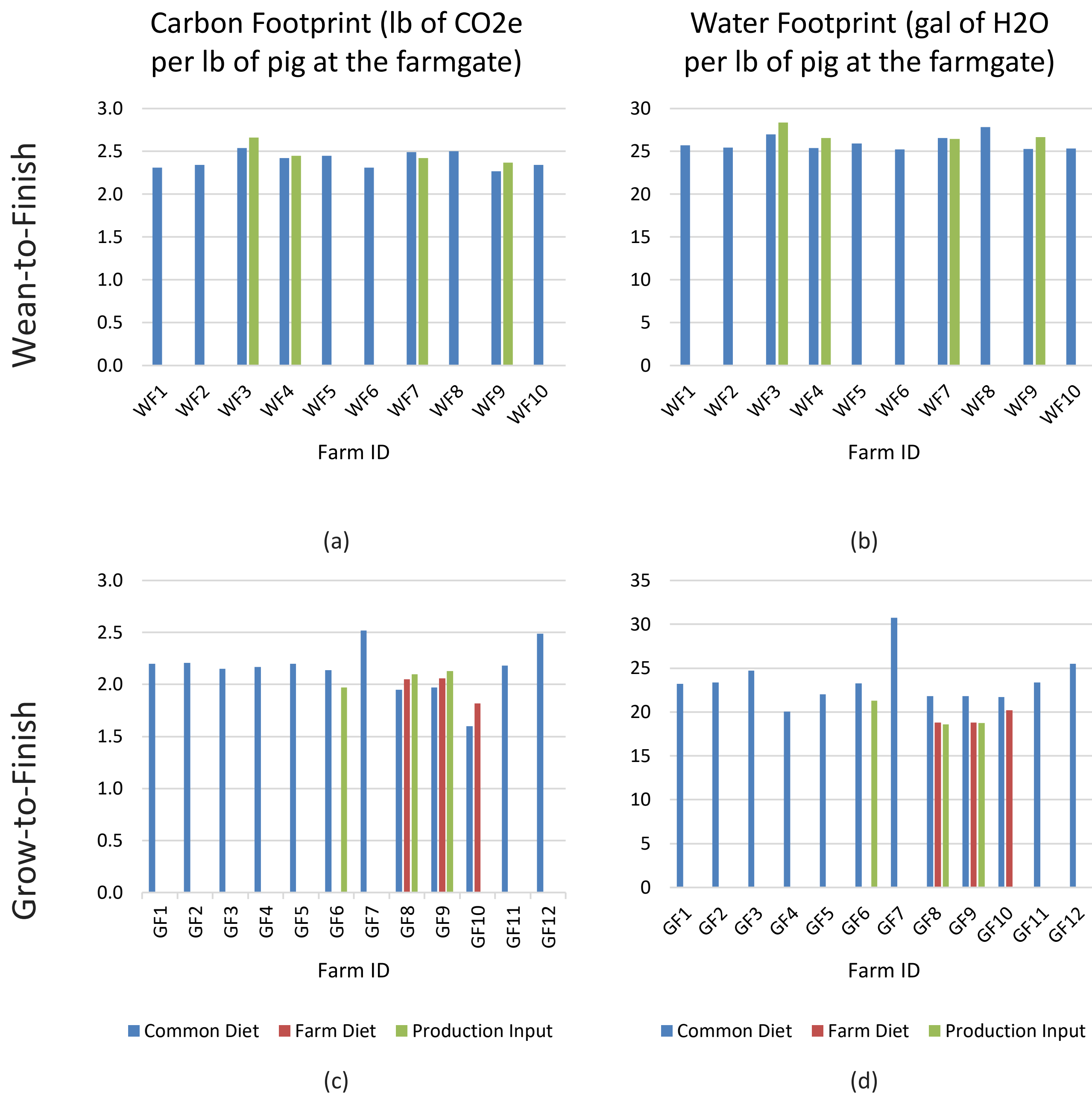


Figure 2 Carbon and water footprints for wean-to-finish and grow-to-finish farms.

Table 1 Descriptive statistics for carbon and water footprints for wean-to-finish and grow-to-finish farms.

Stage of Production Calculation Types	Number of Farms	Average	Standard Deviation	Minimum	Maximum	Per Market Pig
Carbon Footprint		lb CO2e per lb pig at the farmgate				lb CO2e
Wean-to-Finish						
Common Diet[A]	10	2.40	0.09	2.27	2.54	645
Production Input[B]	4	2.48	0.13	2.37	2.66	672
Grow-to-Finish						
Common Diet	12	2.15	0.24	1.60	2.52	615
Farm Diet[C]	3	1.98	0.14	1.82	2.06	545
Production Input	3	2.07	0.09	1.97	2.13	581
Breed-to-Wean		lb CO2e per weaned pig				
Common Diet	4	34.7	6.5	28.9	40.6	
Farm Diet	3	55.5	15.0	38.4	66.4	
Water Footprint		gal H2O per lb pig at the farmgate				gal H2O
Wean to Finish						
Common Diet	10	26.0	0.87	25.2	27.8	6994
Production Input	4	27.0	0.92	26.5	28.4	7335
Grow to Finish						
Common Diet	12	23.5	2.7	20.1	30.8	6727
Farm Diet	3	19.3	0.8	18.8	20.2	5313
Production Input	3	19.5	1.5	18.6	21.3	5518
Breed-to-Wean		gal H2O per weaned pig				
Common Diet	4	623	117	475	739	
Farm Diet	3	514	66	474	590	

[A] We used a common diet and the Pig Production Environmental Footprint Calculator (PPEFC) estimated average daily gain and feed conversion by the pigs.

[B] We used the producer-supplied values for average daily gain and feed conversion in the PPEFC.

[C] We used the producer-supplied farm feed formulations in the PPEFC.

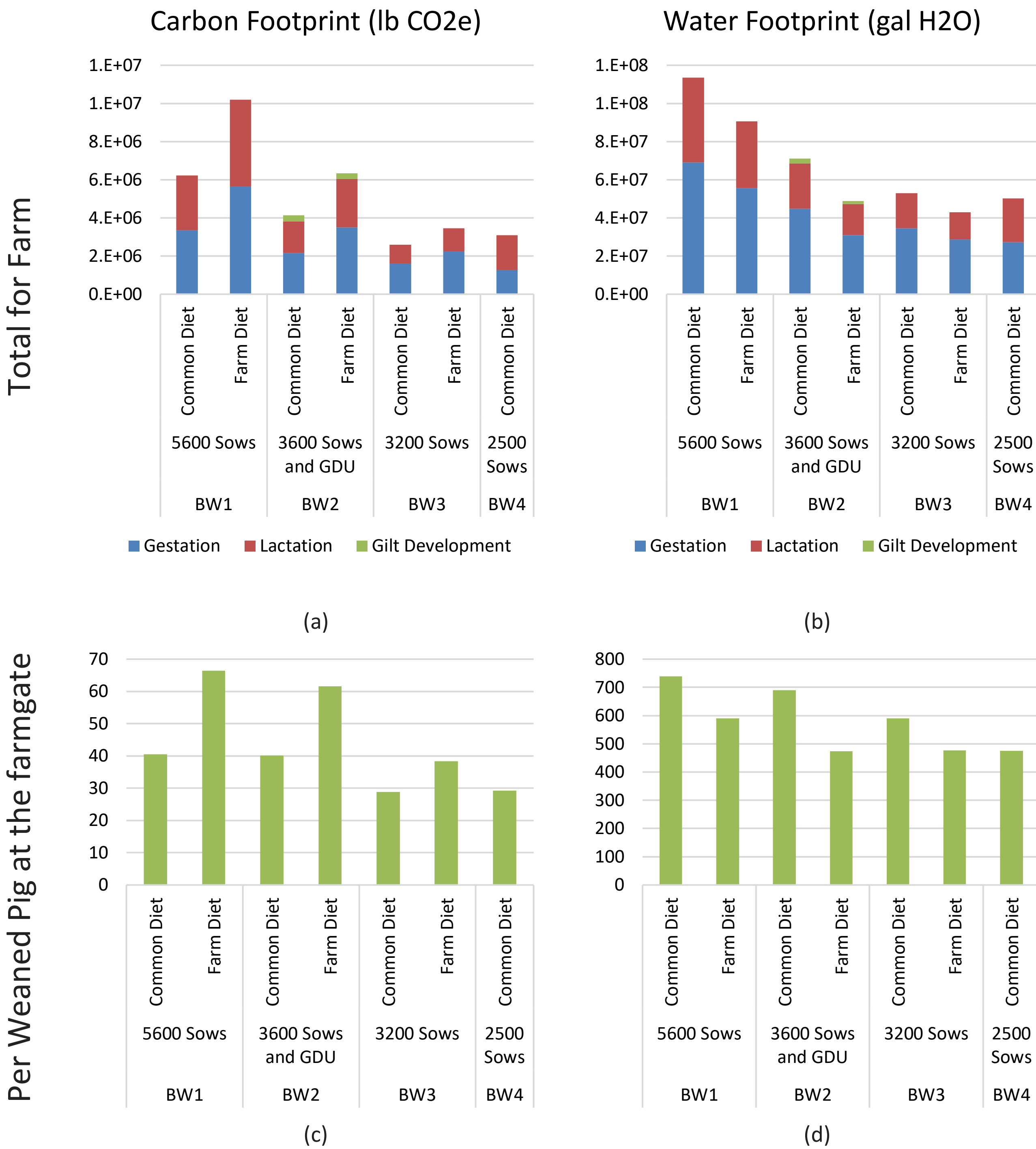


Figure 3 Carbon and water footprints for breed-to-wean farms on a whole farm (a, b) and on a per weaned pig base (c, d).

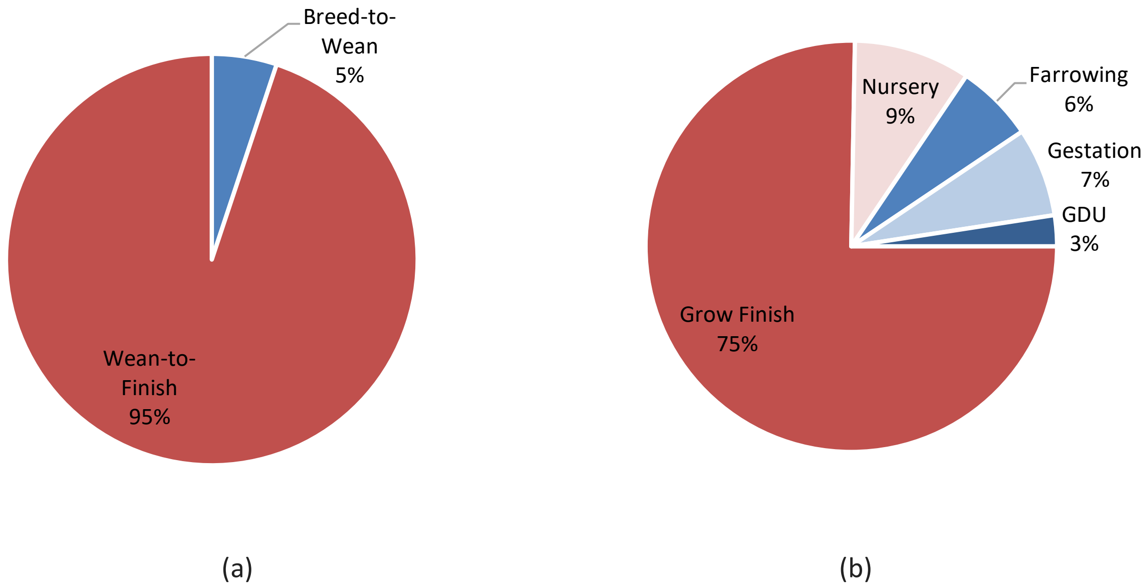
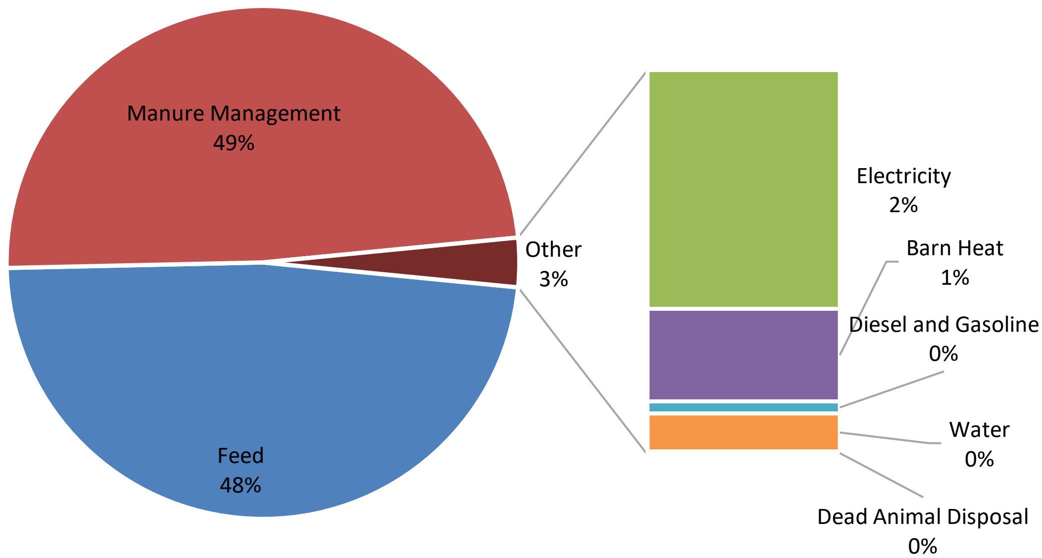


Figure 4 Relative impact of each production stage for the cradle-to-farmgate carbon footprints based on participating farms (a) and a simulation of the WCROC Research Farm using the WCROC model (b; Tallaksen, Johnston, Sharpe, Reese, & Buchanan, 2019).

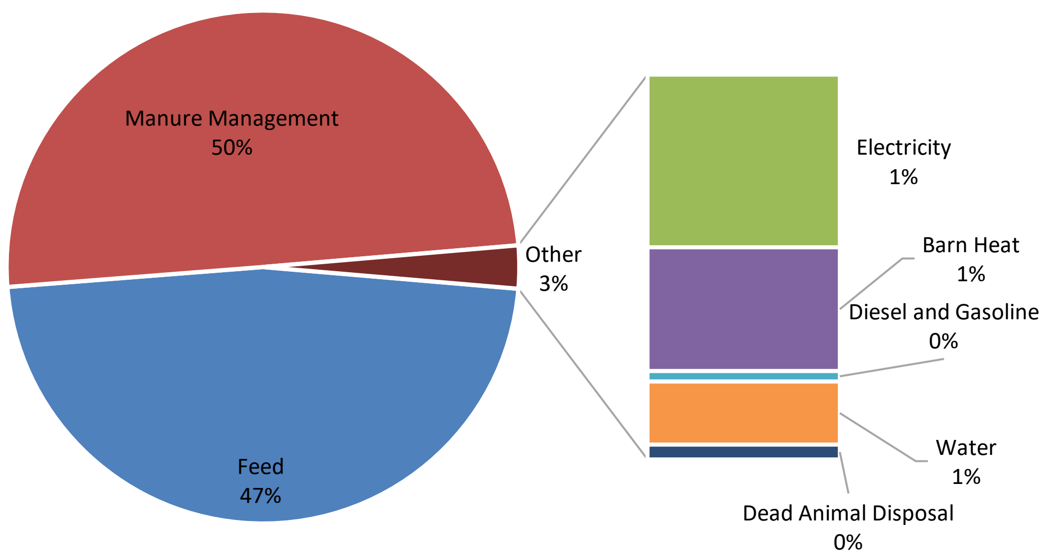
Footprint Components

For each phase of production, we generated weighted averages of the components that contribute to the PPEFC footprints. For cradle-to-farmgate carbon footprints, feed production and manure management account for over 95% of the total greenhouse gas emissions. For the breed-to-wean farm with outdoor manure storage (BW4), the contributions by feed production and manure management were approximately equal, but 18% of the footprint was emissions associated with on-farm energy use. For the other breed-to-wean farms with deep pit manure storage, feed was 50%, manure management was 34%, and on-farm energy use was 16% of emissions.

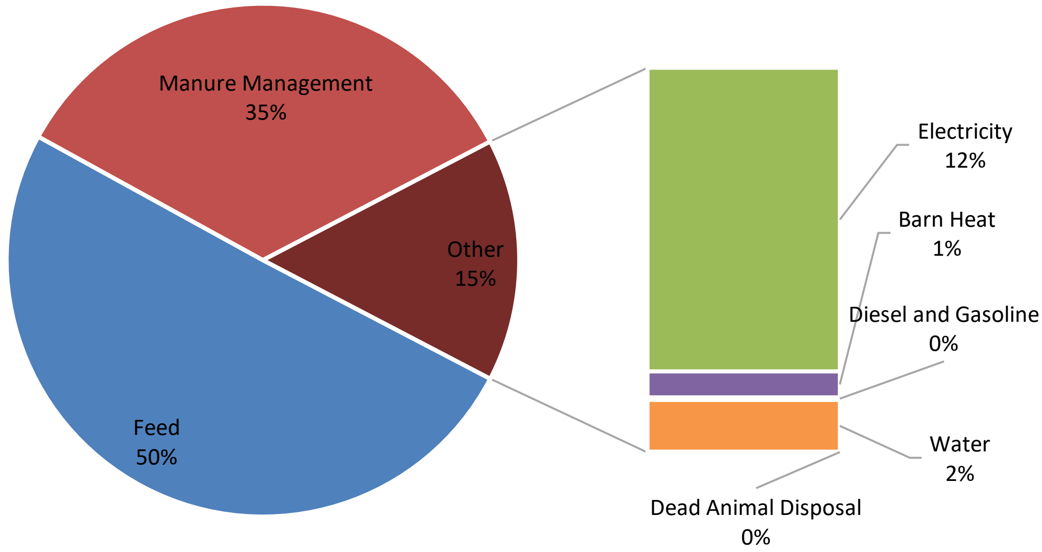
For all production stages, feed production accounted for 90% of the water footprint and the remaining 10% was water usage in the barn for drinking and cooling systems (where indicated by the input data).



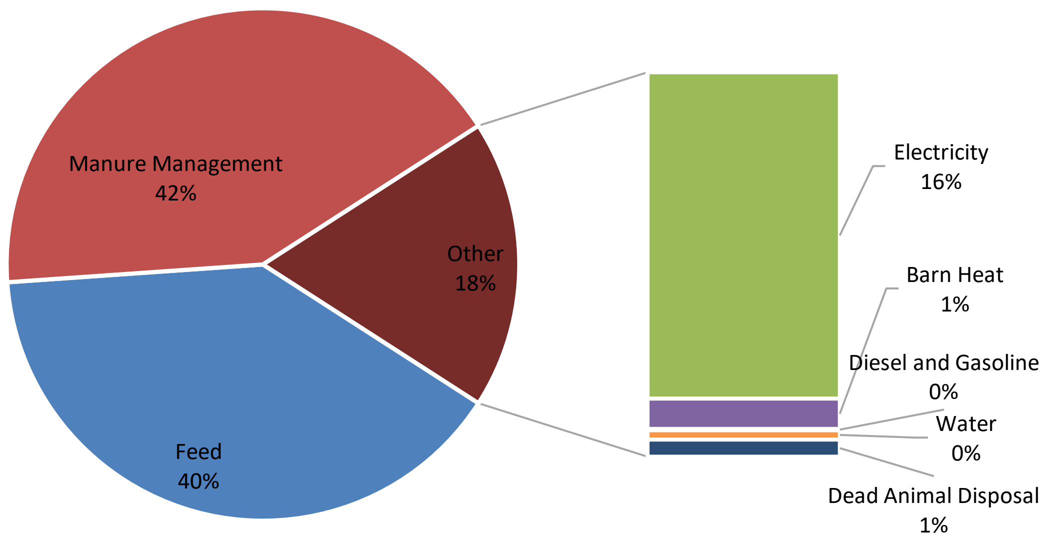
(a) Wean-to-finish farms



(b) Grow-to-finish farms



(c) Breed-to-wean farms with deep pit manure storage.



(d) Breed-to-wean farm with outdoor manure storage.

Figure 5 Components that contribute to the average carbon footprints for wean-finish (a), grow-to-finish (b), and breed-wean farms with deep pit (c) or outdoor manure storage (d).

Objective 2: Measure change in knowledge, interest and trust

The pre-survey question responses showed that overall, the producers we engaged with were aware of and engaged in protecting the environment, but the interest and knowledge in environmental footprints is highly variable. There were 10 participants for the pre-survey.

The most common response of survey participants was no past experience with environmental footprints, though there were instances of producers who have looked into their operation's footprint in the past (Figure 6). Personally asking producers to participate was a reason for participating, but the majority response indicated a desire to be able to address questions about pork production was a major driver for participation (Figure 7). The distribution of responses to the pre-survey question of the ultimate use of the footprint information was distributed among ability to discuss and support the industry, inform future decisions, and simply know their operation's footprint (Figure 8).

Only one participant provided a description of a carbon footprint as "How much carbon related materials are used to produce a pound of pork", and similarly, "How many gallons of water are used to produce a pound of pork" when describing a water footprint. No participants knew the typical average carbon or water footprint for pork production, although one participant did provide their in-barn water usage per pig per year. When asked "What do you think are the top contributors to a typical carbon footprint per pig produced?", the open-ended responses varied from "Not sure" and "Need to know more", to lists that included electricity and other energy use, feed, transportation, air quality, water conservation and land use. When the same question was asked about components to a typical water footprint, drinking water and other in-barn water uses were generally mentioned. One response included growing feed, and another response was "We waste too much water".

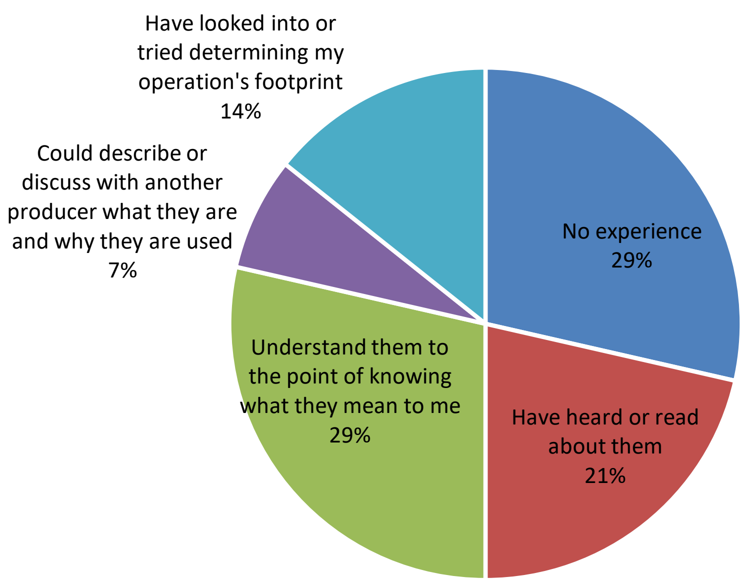


Figure 6 Distribution of responses to the pre-survey question of "What best describes your experience with environmental footprints? (Check all that apply)".

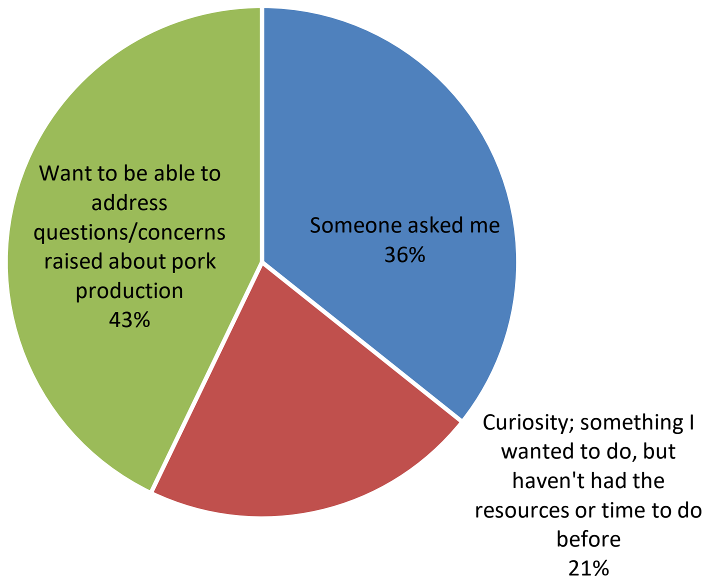


Figure 7 Distribution of responses to the pre-survey question of "What is your reason for participating in this project? (Check all that apply)".

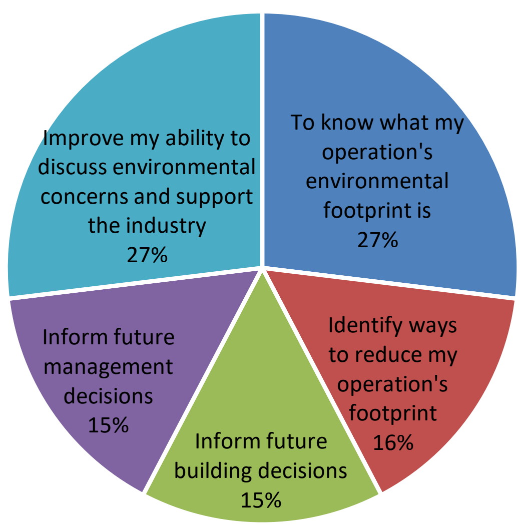


Figure 8 Distribution of responses to the pre-survey question of "What do you hope to gain from participating? (Check all that apply)"

When asked how they consider the environmental sustainability of their operation on a scale of 1 (worst) to 10 (best-ever), the responses ranged from 5 to 8, with average being 7.

The paraphrased areas that producers felt they can improve their environmental sustainability are as follows:

- Water quality; air quality; manganese, magnesium, sulfur
- Better technologies and cost limitations
- Feed mill is close and corn is close and manure hauling is close; rendering could be an area for improvement
- Improve feed conversion
- If you aren't learning you are falling behind
- To know what our footprint is - know where we are. Need to know where we are to make improvements. Utility use, water use, improve feed conversion
- Nitrate tests this year - had to surface apply manure last year; curious how much is lost; need to keep an eye on nitrogen in Karst region
- Rented land not tiled as well as it should be to get crop and biomass established earlier so that plants can retain nutrients. Raise mostly corn and feel corn can add or hold carbon better than other crops
- Manure application and fuel usage
- Cover crops and cow herd

Our method of interacting with producers made the post-survey delivery more challenging. These results are not available at this time.

Objective 3: Identify strategies for meeting sustainability goals

For a farm, Equation 1 and Equation 2 are simplistic versions of how the carbon and water footprints are presented, but also demonstrate the broad areas that producers can focus on for changing the footprints per production metric.

$$\frac{Greenhouse\ Gas\ Emissions}{Unit\ of\ Production} = \frac{Carbon\ Footprint}{Unit\ of\ Production}$$

Equation 1

$$\frac{Water\ Usage}{Unit\ of\ Production} = \frac{Water\ Footprint}{Unit\ of\ Production}$$

Equation 2

From the footprint results, it became clear to us that changes to feed and manure emissions would result in the largest changes to the emissions and water usage by a farm. Table 2 demonstrates the sensitivity of the WCROC LCA model footprint estimates to reductions in contributions solely by housing energy, manure or feed production. However, we also recognize that on-farm decisions related to building design and housing energy can also influence the units of production within a system; greater production efficiency can inversely influence the footprints (Equation 1).

Table 2 The impact of 5%, 10% and 20% reductions in component emissions on the total carbon footprint for a grow-to-finish system (estimated using the WCROC model for regional commercial farms).

	Total Carbon Footprint Reduction		
Production Area	**5%**	**10%**	**20%**
Housing Energy Emissions	0.2%	0.3%	0.6%
Manure Based Emissions	3.3%	6.7%	13.4%
Feed Based Emissions	1.2%	3.0%	6.0%

From engaging with production systems, we also identified opportunities for production systems to take a more direct approach in footprint calculations.

We note that footprint calculations rely on several assumptions and calculations. We also recognize that environmental impacts are only one component to sustainability-based decisions that also consider economics and societal impacts. We briefly discuss these tradeoffs.

Strategy 1: Altering Feed Formulations

The feed consumed is a major contributor to the carbon, water and land footprints for growing pigs. For wean-finish and grow-finish operations, approximately half of the greenhouse gases produced comes from the production of feed ingredients that go into the feed rations. Therefore, if you can change the greenhouse gas associated with the feed by 10%, the overall footprint per pig produced is decreased approximately 5%.

How does altering feed formulations change the environmental footprints for pig production systems?

Greenhouse gas emissions, water use and land use occur during the growth, transportation, and/or processing stages of feed ration ingredients (Table 3). By altering the feed ingredients and mix ratio, the carbon, water and land footprints per pound of feed change (Figure 9). Dried distillers grain (DDG) was one particularly impactful ingredient that resulted in differences between the common diet and producer-supplied farm diets. The DDG inclusion increases the carbon footprint but decreases the water footprint associated with the feed.

Altering diet ingredients, in turn, can influence the rate of feed consumption, conversion of feed to pig mass, the rate of gain by the animals and overall production efficiency. For PPEFC simulations, a change in diet also influenced the estimated volume of manure and manure management-related carbon footprint, but not influence the change in number of animals produced. Thus, the feed has both direct and indirect impacts on the environmental footprints.

Table 3 Sample of common feed ingredients and their environmental footprints per lb of feed.

	PPEFC Footprint Values			**Comparison Carbon Values**	
	Carbon	Water	Land		
Energy Ingredients	lbCO2e	gal		lb CO2e	Source
Corn DDG	1.03	0.0067	0.63	1.0524	Datasmart
Corn DDGS, >10% Oil	1.03	0.0067	0.63		
Corn, No. 2	0.37	0.0776	1.09	0.41844	Datasmart
Soybean Oil	1.04	0.0389	7.36	0.83354	DataSmart
Wheat DDGS	1.02	0.2436	1.3		
Fat, Choice White Grease	1.95	0.0102	1.04	0.6531	Ecoinvent 2.2 (Frischknecht, et al., 2005)
Protein Ingredients					
Blood Meal, Spray Dried	2.28	0.0104	1	2.417	Agrifootprint (Blonk, 2017)
Fish Meal, Menhaden	1.69	0.003	0	0.8887	Agrifootprint (Blonk, 2017)
Milk Whey Powder	12.4	1.8884	13.4	1.01	Agrifootprint (Blonk, 2017)
Soybean Meal	0.4	0.0597	2.8	0.42048	DataSmart
Soybeans, Full Fat	0.34	0.0749	3.57		
Sunflower Meal, 42%,	0.51	0.0028	3.31	0.2323	WCROC data in preparation
Vitamins & Minerals					
Calcium Carbonate	0.03	0.0002	0.05		
Limestone, Ground	0.03	0.0002	0.05	0.216	Ecoinvent 2.2 (Frischknecht, et al., 2005)
Salt	0.27	0.0079	0.03		
Zinc Oxide, 72% Zn	2.49	0.007	0.05	2.832	Ecoinvent 2.2 (Frischknecht, et al., 2005)
Grow-Fin Vitamin Premix	2.08	0.021	0.05		
Nursery/sow Vitamin Premix	3.77	0.0278	0.07		
Vitamin Premix (NB-6508)	5.45	0.0392	0.09		
Trace Mineral Premix (NB-8534)	0.18	0.003	0.05		
Amino Acids					
DL-Methionine	5.13	0.0546	4.09	5.493	Marinussen and Kool (2010)
L-Lysine-HCl	6.18	0.0309	0.12	8.04	Marinussen and Kool (2010)
L-Threonine	17.14	0.2444	0.3	16.98	Marinussen and Kool (2010)
L-Tryptophan	10.18	0.2416	4.18		
Additives					
Paylean 4.5	1.1	0.039	7.3	0.904	US LCA Commons (USDA)
Phyzyme 600	1.9	0.142	2.8	1.9	Mosnier *et al.* (2011)
Tylan-40	42.5	0.0073	1.3		

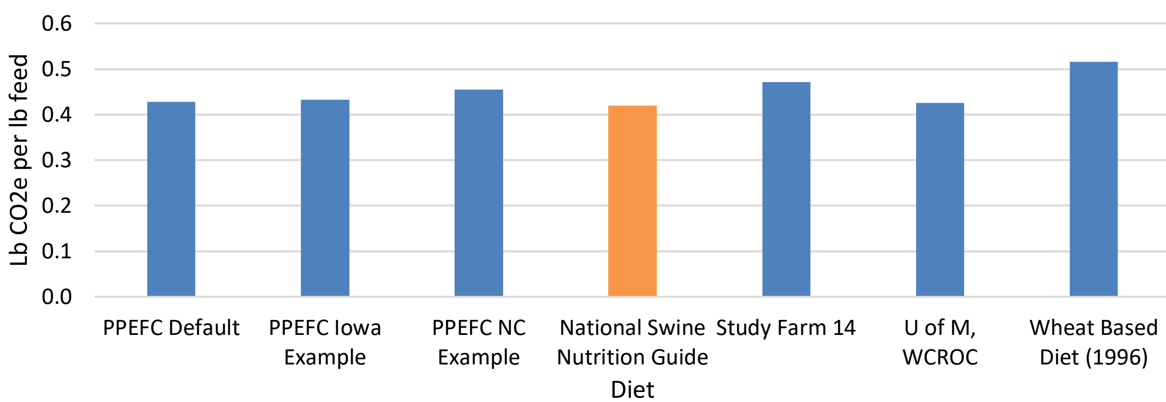


Figure 9 Carbon footprint per pound of feed for grow-to-finish diets (final phase prior to market). The orange bar reflects the "Common" diet used for simulations of all farms.

What are other considerations associated with altering feed formulations?

Typically, productivity is the most important measure of a swine diet. Are you able to generate the same amount of pork with a given diet? Also important is cost of the diet. The producer must balance the economics, productivity, and environmental aspects of their feed choices to meet their expected outcomes.

Another important consideration is ingredient availability. Some agricultural co-products used in feed have seasonal availability that limits their use as a feed ingredient. For example, in some areas, sugar beet pulp may be a viable ingredient during times when sugar beets are processed but not at other times. Producers may avoid less impactful ingredients rather than factoring in the complexity of availability in specialized feed formulations.

While the PPEFC inputs include feed delivery distance, we are unsure if and how the calculator accounts for locally-sourced grain or other ration ingredients. This may be important if the ingredients are sourced from an on-site or local supplier able to deliver ingredients with less impacts than is considered in the background data for the PPEFC model.

Many contract growers are locked into specific feed formulations based on their contracts with purchasers. In fact, the grower might only be responsible for informing the feed supplier that they need more feed and not the specific ingredients in the mix being delivered. Therefore, some producers may not be able to examine feed inputs as a potential area for carbon footprint reductions.

Strategy 2: Manure Management

The manure storage system is a major contributor to the carbon footprint for growing pigs. For wean-finish and grow-finish operations, approximately half of the greenhouse gases produced comes from manure storage emissions of methane, nitrous oxide and other nitrogen gases. Therefore, if you can change the greenhouse gas emissions associated with the manure by 10%, the overall footprint per pig produced is decreased by roughly 5.

In this strategy, we investigate changes to the type of manure storage system and frequency of manure removal. Theoretically, changing the manure composition can also influence greenhouse gas emissions. Manure sampling is discussed in more detail in Strategy 4.

How does manure storage system type change the environmental footprints for pig production systems?

Figure 10 shows the variation in carbon footprints for the same grow-finish farm simulated with a deep pit, lagoon storage or digester (covered lagoon) using the PPEFC. A properly designed and managed lagoon system degrades and stabilizes organic matter, producing methane in the process. Nitrous oxide is a product of incomplete nitrification, and occurs in anaerobic conditions. Methane is also produced by deep pit manure storages, but the anaerobic decomposition process is hampered by higher nutrient concentrations; thus, there are lower methane and nitrous oxide emissions. A digester also promotes anaerobic stabilization of manure, but the methane is captured and a portion of the methane is converted to other forms. In Figure 10, the captured methane offset electricity demand by the farm.

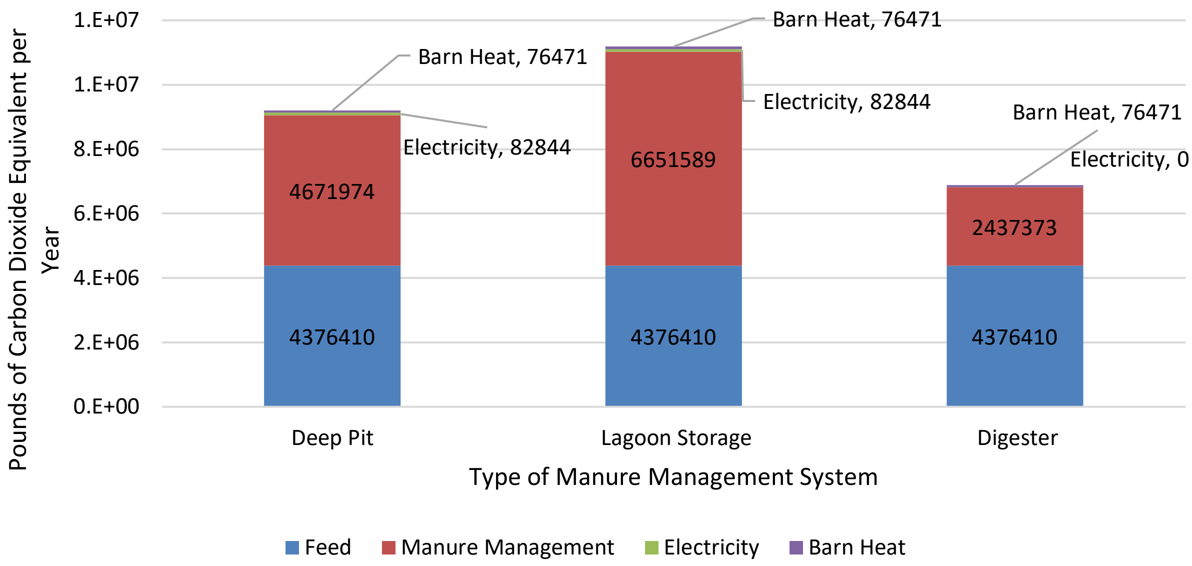


Figure 10 Carbon footprints for an 8,800-hd grow-finish farm simulated with either a deep pit, lagoon storage or digester manure management systems. Note: Minor components that did not differ between simulations were left off this figure.

How does frequency of manure removal change the environmental footprints for pig production systems?

The PPEFC estimates the methane and nitrous oxide emissions released from manure stored on the farm. Methane emission estimates depend on the volatile solids concentration of the manure, the length of storage, the temperature, and the type of manure storage. Nitrous oxide emission estimates depend on the nitrogen content of the manure and the type of manure storage.

The change in carbon footprints for two farms with once or twice per year manure removal from a deep pit are shown in Figure 11. In both cases, removing manure twice decreased the carbon footprint 36%, and the overall footprint for Farm A and B 18%.

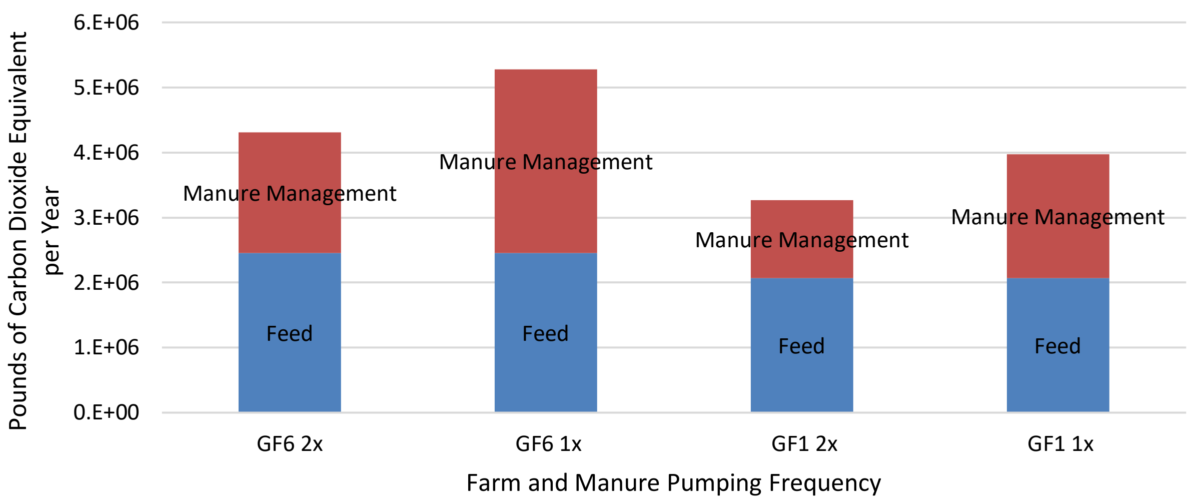


Figure 11 Manure management and feed contributions to carbon footprints for two grow-to-finish farms (4,000-hd capacity) simulated with once per year and twice per year manure removal.

What are other considerations associated with manure storage system type?

Manure storage design must consider local regulations, climate, cost, and both indoor and outdoor environments. All storage systems require proper design and consideration of local water tables and geology. Table 4 shares additional advantages and disadvantages for the three main types of manure storage systems used by swine production systems. Earthen manure storages are not as common as deep-pit systems throughout the region, but are more prevalent as you move south. In the few instances of earthen manure storages in the northern Midwest (i.e. Minnesota), earthen slurry basins are more common than earthen lagoons, since winter weather is not conducive to maintaining sufficient biological activity for manure treatment purposes.

Table 4 Advantages and disadvantages of liquid manure storage types (adapted from Fulhage, Hoehne, Jones, & Koelsch, 2001).

Storage Type	Advantages	Disadvantages
Deep pit storage (below building)	• Relatively high nutrient density • Low/moderate nutrient loss • Manure may be injected or incorporated • No rainfall effects	• More expensive than earthen storage • May have more odor • Animal/worker exposure to manure gases in barn • Relatively expensive application equipment • Solids are more difficult to remove
Earthen slurry basin	• Relatively high nutrient density • Low/moderate nutrient loss • Manure may be injected or incorporated • Less expensive than concrete or steel storages • Can be sized for runoff and minimal fresh water inputs • Opportunities for surface covers to reduce aerial losses	• May have higher odors because of larger surface area • Rainfall adds extra water • May be difficult to agitate properly • Relatively expensive application equipment
Earthen lagoon	• Provides biological treatment of manure • Can be managed with irrigation equipment • Can be sized for runoff and fresh water inputs • Opportunities for surface covers to reduce aerial losses	• May have seasonally offensive odors, especially after extended frozen periods • High loss of nitrogen via volatilization • High phosphorus levels can accumulate in sludge • Agitation may be difficult due to size

What are other considerations associated with frequency of manure removal?

Responsible manure management requires applying the manure nutrients when the crop can use them, but also reducing the risk of nutrient losses to the environment. Local, state and/or federal regulations usually dictate the minimum amount of storage required for concentrated animal feeding operations, with 6 months to 1 year being the norm. Fall application of manure after harvest of crops, when cooler soil conditions reduce the volatilization loss, and before wet or frozen soil conditions occur are best management practices to reduce the risk of nutrient loss after application. Spring application of manure prior to planting situates the manure nutrients in place immediately before use by a growing crop. However, many farmers try to avoid spring application to minimize compaction of west soils by heavy manure application equipment.

Greenhouse gas emissions from soil after application are not directly considered in the PPEFC for a simulated farm. Greenhouse gas losses from land-applied manure or fertilizer are included in the regional estimates for greenhouse gases associated with crop production. We do not currently know of a footprint calculator that integrates farm-specific livestock and manure nutrient management.

Strategy 3: Animal Environment and Husbandry

Environmental footprints can be improved by decreasing resources consumed to achieve similar pig performance (improve efficiency) and/or by improving performance for similar level of inputs on the farm (improve productivity).

What are some practices to improve swine housing?

Building systems are a smaller component of the environmental footprints than either feed use or manure (Table 2). However, reducing energy use on the farm has a direct payback to the producer and at the same time improves the fossil energy footprint of swine production. Since animal housing and husbandry decisions are directly under the producers' control, they may be able to make changes in these areas that improve their pocketbook and the environment. Figure 12 demonstrates the variability and proportional differences in on-farm energy use, water delivery and animal mortality management between grow-finish farms of various sizes and ventilation styles. One farm (GF5) has solar panels that offset all on-farm electricity use.

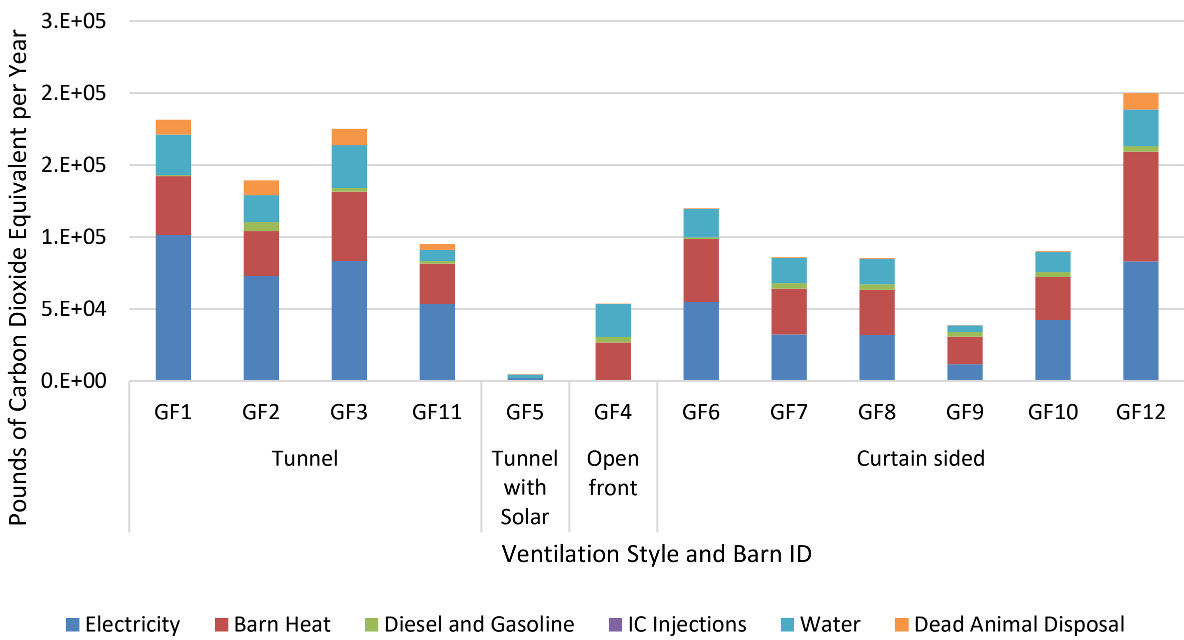


Figure 12 On-farm energy, water delivery and mortality management components that contribute to carbon footprints for grow-to-finish farms, grouped by ventilation style. Note: farms have varying capacity and efficiency of resources is not reflected in this figure

Practices that reduce housing system energy use without changing production often rely on building efficiency or operations. For example, upgrading lighting is an easy and cost effective step for many operations as new lighting technologies emerge. The new lights reduce the kWh of electricity used, but achieve the desired room light levels. In most situations, this change is not expected to affect pig performance. One of the participating producers replaced 60W incandescent bulbs with 9W LED lights, which noticeably lowered the farm electric bill and resulted in a greatly reduced impact of lighting to the farm's carbon footprint (albeit a small change for the overall farm). Of course, LED bulbs are more expensive, so financial costs and benefits need evaluation also to assure a reasonable payback period for investing in new lights.

Heating and cooling systems are of particular importance as they use the majority of electricity and heating fuels. Identifying key settings of control systems for a particular barn and its associated heating, cooling, and ventilation units can often reduce energy use and improve the indoor environment for livestock at the same time. Cleaning fans and replacing worn equipment can also reduce energy for indoor space conditioning. Another practice tested to reduce building inputs is reducing night-time temperatures for swine barns. Work by Johnston et al. (2013) found that a decrease in night-time temperatures in the nursery reduced heating fuel use by 30% and electricity by 20% with no noticeable difference in productivity.

In considering strategies for building energy reductions, it is important to understand that different production stages have very different energy input needs. The longest stage of swine production, the grow-finish stage, uses relatively modest amounts of energy inputs. Targeting high-energy use phases (Breed-to-wean and Nursery) for energy conservation may be a better approach. One example is creep-space heating in the farrowing operation. Typical heat lamps use a great deal of energy, much of which radiates as light or heat away from the piglets. Preliminary research suggests that heat mats may be a better option. They both use less energy and likely have a longer lifespan than heat lamps.

What are some practices to improve animal health and productivity to improve footprints?

Animal health affects footprints in multiple ways. Equations 1 and 2 include the production metric as part of the environmental footprint. Increasing swine productivity using the same inputs lowers the overall environmental impacts per lb or pig produced. Healthy pigs are more likely to be productive pigs. Maintenance energy (feed and fuel) requirements are lower for animals that grow quickly and do not have to fight off disease challenges. Sick animals that die on the farm end up consuming resources with no useful product generated. Strategies that can improve animal growth efficiency can result in lower footprints per pound of pig produced.

Strategy 4: Record Keeping

Many of the producers we engaged with were willing to share their production metrics. Furthermore, many of the farms, and in particular the larger production systems, also had annual summaries for many of the footprint components like feed, electricity and on-farm water use.

Footprints require more than simply the amount of energy or feed used. For example, greenhouse gases are emitted during the production of electricity versus the use of electricity. The amount of greenhouse gas produced ties back to the regional electrical generation system that a farm is tied into. As another example, corn production uses varying amounts of rain and irrigation water depending on the climate and region. The LCA world has developed public tables for regional and/or commodity specific greenhouse gas emissions and water use per mass or volume of product.

How does record keeping change the environmental footprints for pig production systems?

Accurate records can be incorporated into footprint analyses if the records are for the appropriate scope, and you know where to look for the "factors". The calculator-based footprints cannot accommodate all forms of management or husbandry changes that have potential to influence energy usage, animal production or both. A producer's records may do a better job of capturing the change and effect of the change in farm-level inputs and productivity, respectively.

A producer may wish to start with a PPEFC-generated footprint. Annual summary records of electricity and fuel use could replace the "farm activity source amounts", and with an appropriate factor, translate to carbon dioxide equivalent emissions. We recommend consulting with an LCA-specialist to look up the appropriate factors, recognizing these factors do change over time.

Some facets of the footprint calculator are more challenging for "do-it-yourself" calculations than others. Manure management system emissions, for example, are more involved calculations that consider time between manure removals and temperature (Dong, et al., 2006). Feed consumption, animal growth and units of production (lb of pig at the farmgate or pigs leaving the farmgate) are closely tied, and we recommend using records for these different inputs simultaneously.

From our experience, a deeper understanding of the calculation process and factors opens the discussion to the components that producers can and cannot directly control. For example, a farm's footprint for electricity depends on the amount of renewable energy use in a region. While the producer cannot necessarily choose the amount of renewable energy use in a region, there are opportunities to engage in regional discussions and policy making.

Note: For grow-finish and wean-finish farms, the production metrics of ADG and FCR can be inputs to the calculator. However, the calculator frequently failed to merge these producer-supplied inputs with the production calculations (error message stated the NRC equations could not bend enough). For sow farms, pigs weaned is an important metric and we were able to craft pig flow to better match producer-supplied numbers of pigs weaned.

Project Presentations

The project goals and learnings were shared through multiple presentations:

- 2018 Allen D. Leman Swine Conference, St. Paul, MN; approximately 40 people
- 2019 Midwest Farm Energy Conference, Morris, MN; approximately 50 people
- 2019 Allen D. Leman Swine Conference, St. Paul, MN; approximately 40 people

The compiled footprint information will continue to be shared through Extension and other producer outreach venues to raise awareness of environmental footprints and opportunities to improve farm resource efficiencies in our region.

Discussion:

Producer Engagement in Footprint Calculations

Our engagement and survey of producers suggests that while the producers feel strongly about their environmental impact and "doing the right thing", going through the footprint calculation process is not a high priority. We observed many instances of producers we contacted and personally asked to participate who were willing to help as a service to the industry, but saw less direct benefit for their own operation. The producers we engaged may also tend to be the early adopters and involved with the industry, since the contacts came from our existing networks of persons who have previously engaged with Extension or swine industry leadership. For the producers managing individual farm sites, one producer's feedback seems to sum up the general sentiment we experienced: 'We are out there trying to survive, focusing on doing the right thing and preserving resources while doing so'. While the response to personal requests for participation was positive, it was sometimes challenging to get the follow through. We acknowledge follow-up was also dependent on the project personnel time and effort.

We observed that environmental managers of larger production systems are already working towards defining or measuring sustainability-related goals/metrics using a variety of methods and processes. The environmental managers we interacted with were interested in how the PPEFC and this project aligned with their own internal, sustainability efforts, but also did not want to divert significant time away from their own efforts. These managers tend to have access to many data across their sites that they want to use. The producers we engaged with multiple farms used this as an opportunity to look at differences between old and new construction. Strategy 4 is an option to merge these efforts, but does require access to resources and persons associated with LCAs.

While carbon and water footprints are becoming more popular terms in the environmental management realm, their meaning and scope are still not well-understood (Figure 6). Feed and manure storage emissions were rarely identified by the producers we worked with as key components to the environmental footprints. The producers more readily identified components within their control, under their day-to-day management. We did not emphasize the cost calculation by the PPEFC. We realize the potential this calculation has when investigating different scenarios; however, use of the PPEFC simply for baseline calculations is more likely in the near future as a first step. Our project team also learned a lot in this process, and benefited from having a team member with LCA experience to explain some of the calculations and processes.

Can Extension be a liaison to producers for these calculations? Yes, but our experience was that comfort with the calculator inputs, process, and results did require practice. We had the benefit of a team to discuss issues and challenges as they arose, and a database of results to compare to for different production systems. The results from this project help provide baselines for other people, Extension or otherwise, to compare results to. We do not yet know how well this engagement will translate to longer-term retention, trust and engagement in footprint exercises.

The following suggestions and observations may assist in producer engagement by Extension or other outreach personnel for environmental footprint calculations in the future.

- Use personal requests through existing networks of collaborators in the industry. We also invited participation after Extension visits for other questions or concerns. Working through environmental managers of larger production systems can also enable footprints for series of farms with similar inputs to the PPEFC, reducing the time requirement.
- We often engaged producers via email, and gathered data using the worksheet available online. This form worked well for wean-finish and grow-finish farms. More of a narrative approach would benefit data gathering for breed-wean farms to fully understand sow flow through breeding, gestation and farrowing, and gilt replacement. Working via email was not as conducive to follow-up discussions of results and questions.
- Feed formulation is site specific and a major component to footprints. However, having a common set of diet formulations readily available in the PPEFC makes the first set of calculations easier. There is opportunity for a follow-up request and calculation with the farm specific ration.

Environmental Footprints

The footprints are estimates, with a suite of assumptions informing the calculations. The footprints are important for providing baseline estimates. Understanding the assumptions in the calculations gives direction for future LCA work, environmental study and producer actions.

There was generally a small range between footprints for wean-finish and grow-finish phases for common feed, manure management and ventilation systems. The common feed formulations we used across all farms were corn and soybean meal based. These diets do not necessarily reflect the typical diet currently used in the region that contain DDGs. However, the calculator does not necessarily account for locally sourced grain, other diet ingredients (including DDGs), or on-farm manure nutrient recycling in place of inorganic fertilizer by integrated livestock and crop farms. Integrating the PPEFC calculator with a crop-based calculator has potential to better reflect specific farming and manure nutrient utilization, but this would also complicate the input and calculations for the user.

The deep pit manure storage system used by all participating farms except one is recognized for having lower emissions (Fulhage, Hoehne, Jones, & Koelsch, 2001). Regional climate, terrain and regulations influence manure storage system selection. The typical manure storages of deep pit under roof, outdoor manure storage and anaerobic lagoon each have benefits and drawbacks. For deep pit manure storage, lower carbon footprints through reduced greenhouse gas emissions are a benefit that is not commonly acknowledged. Anaerobic digesters can further reduce the manure management component for footprints; however, incorporating digestion would require a systematic change in manure storage for the Upper Midwest region.

The following suggestions and observations may assist in the environmental footprint calculations and producer interface in the future:

- All of the producers we worked with appeared to have some annual summaries of data like electricity, water and/or feed usage and were prepared to share them with us. This information was necessary in earlier versions of the calculator. Perhaps a hybrid calculator that can incorporate these data and provide calculated values where input information is not available will promote more usage and more accuracy of footprint estimates.
- The calculator is better at making system design versus management comparisons. A hybrid calculator may make management style comparisons easier.
- The PPEFC estimates draw data from LCA tables of background activities which change over time. The footprint calculator is deployed online with the ability to provide these updates to users. There is opportunity to maintain accuracy of the PPEFC estimates over time by updating the tables regularly. When updates are made to the tables used in the PPEFC, this is also an educational opportunity to raise awareness of the PPEFC.
- In the Upper Midwest region, sow farms frequently exceed 5,000 sows, which is a current limit in the calculator. The temporary fix is to divide barns and simulate each half separately - but additional inputs like the ventilation and heating system components also need to be divided.
- The farm-specific feed formulations that we entered always included a trade name ingredient that was not readily apparent in the list of feedstuffs in the PPEFC. More frequent updates to the LCA tables may address this challenge. Alternatively, a sensitivity analysis for minor ingredients may help identify the relative impact of these minor diet ingredients, and the need for their addition in the PPEFC.
- The project team suggests revisiting the following input data to the PPEFC.
    - Manure per truckload is requested in lb/truckload versus gallons/truckload. If this question is posed in conjunction with the description of the manure management system, gallons or pounds could be asked for liquid and solid systems, respectively.
    - The option for immunocastration and the inclusion on the reports raised questions by producers, particularly when abbreviated as IC.
    - The project team and producers did not quickly grasp the term “maximum allowable approach to outside temperature” for ventilation system description.

- The supplemental cooling option of misters and supplemental heating options for nursery or wean-to-finish barns were not available.
- The gestation farm entries for average age and weight of sows and gilts entering a gestation barn is usually a guess.
- Farrowing barns in this region empty the subfloor manure storage into the deep pit manure storage. We are unsure how to accurately depict this manure storage system in the PPEFC.

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Appendix A

Table 5 Series of common diets formulated based on the National Swine Nutrition Guide (USPCE, 2010)

Phase	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Gestation**	**Lactation**
Start Day for Phase[A]	**1**	**4**	**8**	**18**	**38**	**67**	**90**	**111**	**132**		
						%					
Ingredient											
Corn, yellow dent	30.21	35.78	54.20	65.96	72.96	79.25	83.29	86.53	90.16	81.60	66.47
Soybean meal, 46.5%	17.57	19.45	27.71	30.35	23.66	17.68	13.83	10.77	7.29	14.54	29.85
Whey, dried	29.99	25.00	10.00								
Fish meal	8.00	7.00	3.00								
HP 300	8.00	7.00									
L-lysine HCl	0.25	0.26	0.32	0.40	0.40	0.40	0.38	0.36	0.34		
DL-methionine	0.2	0.20	0.15	0.15	0.11	0.08	0.07	0.04	0.03		
L-threonine	0.11	0.11	0.12	0.15	0.14	0.13	0.12	0.11	0.11		
L-tryptophan	0.03	0.03				0.01	0.01	0.01	0.02		
Soybean oil	4.3	3.7	2.00								
Monocalcium phosphate	0.44	0.5	1.10	1.41	1.21	0.98	0.85	0.76	0.68	1.84	1.76
Limestone	0.25	0.32	0.85	1.02	1.02	0.97	0.94	0.91	0.88	1.31	1.22
Salt	0.03	0.03	0.03	0.35	0.30	0.30	0.30	0.30	0.30	0.50	0.50
Zinc oxide, 72% ZN	0.42	0.42	0.28								
Vitamin Premix[B]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Trace Mineral Premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

[A] Day post weaning when feed phase starts.

[B] Premix is specific to stage of production (i.e. nursery, grower, sow)