Title: An Updated Economic Assessment of New Swine Gestation Facility Investment

Principal Investigator: Dr. Lee L. Schulz[1]

Institution: Iowa State University[1]
University of Minnesota[2]

Co-investigator: Dr. Joleen C. Hadrich[2]

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Industry Summary: While current economic conditions do not necessarily support investment in production facilities, at some point widespread investment will occur. Each pork producer will face decisions at the farm level about which product channels they will supply based on the costs and incentives to produce. Some producers will be legally required by state laws to abandon the use of certain production practices and the facilities that support this production which will inflict significant costs and inefficiencies on producers and the entire pork value chain. Other producers will be reluctant to make costly investments to target specific markets, unless compensated with guaranteed long-term premiums. The overriding objective of this study was to conduct an economic analysis of investing in new gestation housing facilities for a farrow to wean operation. Several approaches were used to accomplish this objective. Existing literature and public information were collected, reviewed, and summarized to establish baseline values on gestation facility types and housing practices, production performance differences, and cost estimates. Economic models were then developed to estimate the net present value (NPV) to a producer from investing in new gestation stall housing versus conventional group housing versus group housing with increased square feet per sow systems. The latter case would be consistent with recent laws requiring farmers to provide a minimum amount of square feet to breeding pigs in gestation. A sensitivity analysis was then conducted to understand how NPV estimates are impacted by feed and non-feed operating costs, interest rates, sow productivity, and up-front building costs. The NPV analysis found gestation stall housing to have a positive NPV of $7.81 million for a 6,400 sow unit. This suggests that a producer will make a larger return on the gestation stall housing facility investment than the discount rate used for the analysis. Therefore, from an economic standpoint, this investment should be made. A 6,400 sow conventional group housing facility has an estimated negative NPV of $1.52 million. The conventional group housing system NPV had the same base revenue economic assumptions as stall housing, however differences occurred with sow productivity and input costs. So, without a price premium for conventional group housing, the investment shouldn't be made. When we apply the conventional group housing sow productivity and operating expense parameters to the group housing with increased square feet per sow facilities, of 4,800 and 6,400 sows, with their associated investment levels, we observe large negative NPVs. The revenues generated over the asset's useful life do not cover the operating and fixed expenses of the system. Due to the negative NPV, the investment should not be made. Large price premiums for group housing with increased square feet per sow would be needed to make it an economically viable investment. The negative NPVs continued to worsen

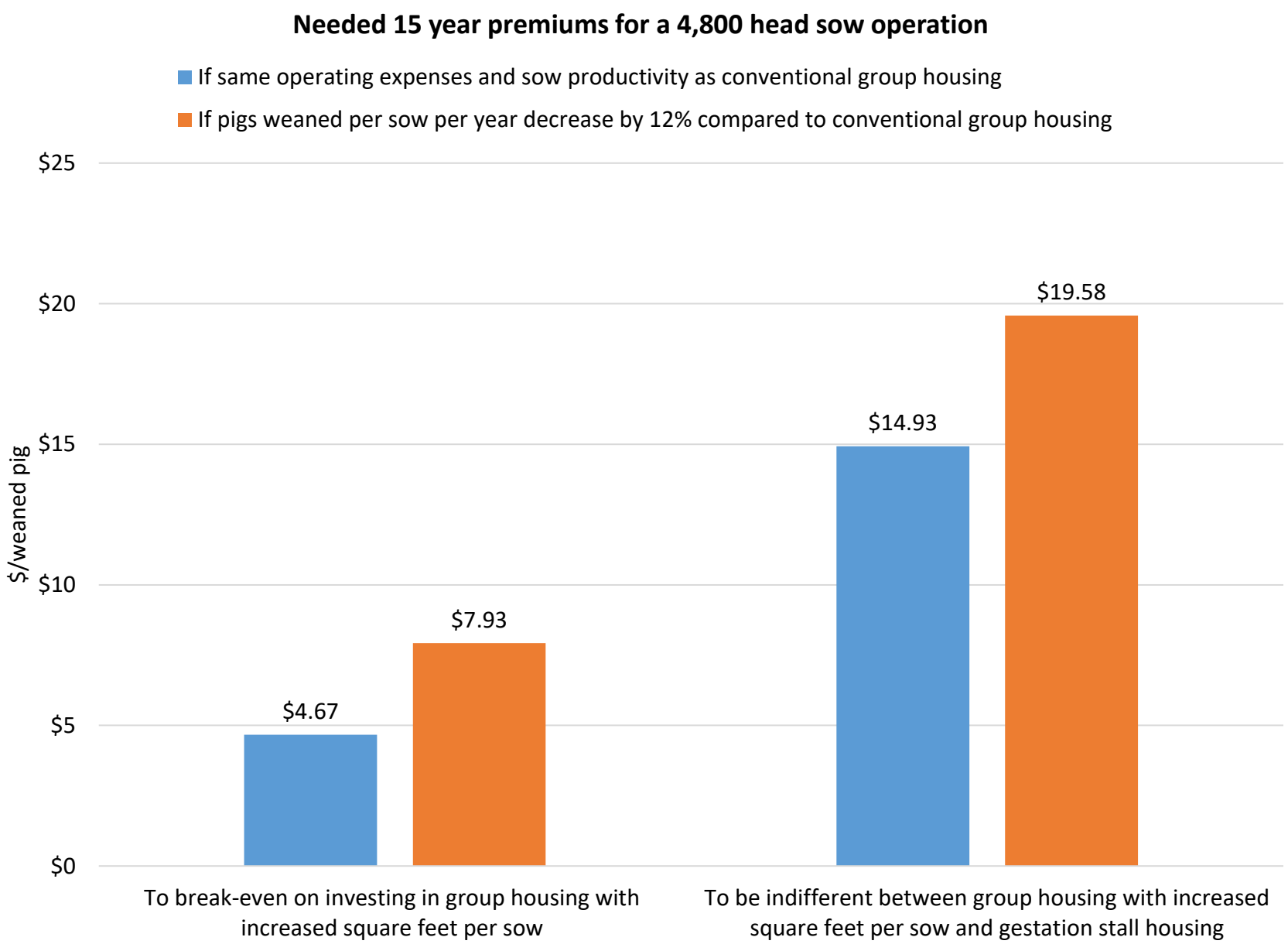
as sensitivity analyses were conducted by increasing selected costs as well as adjusting productivity parameters based on information collected from multiple sources.

Key Findings

- Each pork producer making a new facility investment decision wants to ensure that they will not be any worse off with the new investment. For a 6,400 sow farm, the premium needed to make a producer break-even on investing in group housing with increased square feet per sow is $5.07 per weaned pig. This assumes that the group housing with increased square feet has the same operating expenses and sow productivity as conventional group housing, all that differs is the facility investment cost. A premium of $12.79 per weaned pig is needed to make a producer indifferent between group housing with increased square feet per sow unit and gestation stall housing (which has higher productivity and lower costs). Critically, these premiums would be required over a 15 year period. For a 4,800 sow group housing with increased square feet per sow unit, the premiums needed would be $4.67 and $14.93 per weaned pig to break-even on the investment and be no worse off compared to gestation stall housing, respectively.
- Information collected from multiple sources indicates the likelihood of increased operating costs and lower productivity in group housing with increased square feet per sow compared to conventional group housing and stall housing. Differences may narrow over time, however, impacts are incurred every period making any differences notable over time. If pigs weaned per sow per year decrease by 12%, then the premium for group housing with increased square feet per sow must increase from the base scenario to break-even on the investment or be no worse off than using gestation stall housing. The premium needed for the 4,800 sow unit to break-even is $7.93 per weaned pig and increases to $19.58 per weaned pig to be equivalent to stall housing. For a 6,400 sow group housing unit with increased square feet per sow, premiums of $8.39 and $17.16 per weaned pig are needed to break-even and be indifferent compared to gestation stall housing, respectively. Required premiums escalate quickly under scenarios where relative costs notably increase and productivity markedly declines. Again, any premium would be needed over an entire 15 year period.
- Operations of the size level in our study are often some of the most efficient in the industry. They have achieved this efficiency due to cost savings and management potential. Farms with cost advantages will be better positioned to transition to group housing with increased square feet per sow. They will have lower relative premiums required to be indifferent between stall housing, conventional group housing, and group housing with increased square feet per sow.

Keywords: Capital Budgeting, Economics, Gestation Housing, Net Present Value, Non-carcass Merit Premiums, Pork, Sows, Swine

Scientific Abstract: Same as industry summary.


Needed 15 year premiums for a 4,800 head sow operation
If same operating expenses and sow productivity as conventional group housing
If pigs weaned per sow per year decrease by 12% compared to conventional group housing
$25
$20
$15
$10
$5
$0
$/weaned pig
$4.67
$7.93
$14.93
$19.58
To break-even on investing in group housing with increased square feet per sow
To be indifferent between group housing with increased square feet per sow and gestation stall housing

Introduction

Few things have been more contentious in recent years for the U.S. swine industry than discussions around gestation housing. The gestation period is from conception to birth, which is 114 days (3 months, 3 weeks and 3 days) in swine. Determining how to house sows in gestation is a critical farm management decision informed by animal-welfare and production considerations. Several states have passed and have begun implementing sow housing regulations over the past two decades. See Schulz and Tonsor (2015) and USDA-ERS (2022) for a detailed discussion of the legal framework underlying provisions of animal housing in the United States and a timeline of events and states involved.[1] In addition to regulatory pressures, pig production firms and food companies have considered, and some have moved towards, certain sow housing practices and policies. The transition from gestation stall to group pen housing has been the most common adjustment being discussed, or made, within the industry (Buhr, 2010; Schulz and Tonsor, 2015). The earliest laws centered on having "sufficient space" to allow for covered behaviors with some states extending bans on particular practices including sow gestation stalls, veal calf stalls, and conventional cage systems for laying hens (USDA-ERS, 2022). More recently, laws have had more specific requirements including California's Proposition 12 that was passed on November 6, 2018 that requires a minimum of 24 square feet of usable floor space for each breeding pig. This provision went into effect on January 1, 2022. However, the rules for compliance were not finalized until September 1, 2022 making specific requirements of pork sellers and their suppliers unclear. At the same time, the Supreme Court of the United States agreed to hear a legal challenge against Proposition 12. Oral arguments were heard on October 11, 2022. Application and implementation of the rules were delayed, via an injunction, until the outcome of the Supreme Court decision. On May 11, 2023, the Supreme Court upheld Proposition 12. With the Supreme Court decision, enforcement began on July 1, 2023.[2]

In addition to on-farm production practice requirements, Proposition 12 has retail sales restrictions that prohibit the sale of pork originating from animals kept in gestation stall systems or their direct offspring (USDA-ERS, 2022). For the remainder of 2023, the California Department of Food and Agriculture intends to focus Proposition 12 implementation resources on 1) outreach to ensure that all distributors who are required to register do so; 2) accreditation of third-party certifying agents so that when third-party certification is required for producers and distributor registrations beginning on January 1, 2024, producers and distributors have more options; 3) certification of producers and distributors; and 4) complaint-based investigations (CDFA, 2023). Question 3, a 2016 Massachusetts state law that was passed, was set to go into effect on August 15, 2022. It would ban any uncooked whole pork meat sold in the state that does not meet specific sow housing requirements, regardless of where it was produced, plus the law would not allow the transshipment of whole pork through the state. The U.S. District Court for the District of Massachusetts issued a stay beginning

[1] On July 26, 2023 New Jersey governor signed legislation (A-1970/S-1298) requiring the State Board of Agriculture and the Department of Agriculture to adopt rules and regulations concerning the confinement, care, and treatment of breeding pigs and calves raised for veal.

[2] In June 2023, a California Court amended a previous order effectively extending the enforcement date until December 31, 2023 for non-compliant pork in inventory as of July 1, 2023 (CDFA, 2023).

August 11, 2022 until 30 days after the Supreme Court decided the case brought against Proposition 12. On July 10, 2023, a U.S. District Court for Massachusetts judge extended the current stay on implementation of Question 3 until August 23, 2023.

While current economic conditions do not necessarily support investment in production facilities, at some point widespread investment will occur. Each pork producer will face decisions at the farm level about which product channels they will supply based on the costs and incentives to produce. Some producers may be legally required by state laws to abandon the use of certain production practices and the facilities that support this production which will inflict significant costs and inefficiencies on producers and the entire pork value chain. Other producers will be reluctant to make costly investments to target specific markets, unless compensated with guaranteed long-term premiums.

Expansion or investment decisions take longer to execute than do contraction or disinvestment decisions as, in most cases, production facilities must be built. Investment decisions potentially have a 20 to 30 year impact on pork supplies, since facilities placed into production will likely remain in production, even if with multiple owners. It is important to remember that there is a relatively long lead-time involved in investment decisions. Take for example, expansion of the breeding herd to enter a particular market or capture additional market share. With a 100-sow herd, adding ten sows is a 10% increase in inventory and something that could be done with no change in facilities. Today, the most common increases or changes in on-farm breeding herd inventories require multiples of 2,500 to 5,500 females (Brumm, 2014). In addition to the financial planning involved, this growth involves facility siting, sourcing gilts, securing a new labor pool, possibly establishing a relationship with a new feed mill, among other considerations.

A decision to construct new production facilities today will not result in pigs for almost two years (Brumm, 2014). At the same time, a decision to expand locks a production system into a flow of pigs that they will be producing even during possible lengthy periods of minimal, if any, profits. Once a sow unit is started up, it is not necessarily possible to stop the flow of pigs in tight economic conditions due to the many commitments associated with the facility. Recent periods of more input and output price variability have created a “new price environment.” More uncertainty likely alters the risk–reward relationship as producers consider investment in production facilities. The producer decision of investing in a new facility and the type of facility to build is an important one that needs more attention.

Objectives

The overriding objective of this study is to conduct, within the limitations of current knowledge, an economic analysis of investing in new gestation housing facilities for a farrow to wean operation. There is still much that is not known about increasing the square feet per sow in group housing. This holds at least as much for the costs as it does for the productivity impacts. Hence, the assessment to be presented here is more demonstrative than definitive. Still, using available data, the analysis employs a detailed and transparent method to assess new facility investment alternatives. We aim to:

1. Provide a review and reporting of existing literature and public information to establish baseline values on gestation facility types and housing practices, production performance differences, and cost estimates.
2. Develop economic models to estimate the net present value (NPV) to a producer from investing in new gestation stall housing versus conventional group housing versus group housing with increased square feet per sow.
3. Conduct sensitivity analysis of NPV estimates to key inputs including feed and non-feed operating costs, interest rates, sow productivity, and up-front building costs.

Materials & Methods

The analysis requires synthesis of existing information, gathering of new data, and developing economic models. First, U.S. Department of Agriculture (USDA) data from the National Animal Health Monitoring System (NAHMS) swine studies are used to examine trends in facility type and housing practices of gestating sows. Beyond assessing trends, important context is provided on where existing data collection and reporting efforts could be expanded to address data gaps and provide additional insights into sow housing practices.

NAHMS swine studies in 1995, 2000, 2006, and 2012, are comparable over time because of the consistent way in which the surveys were conducted and processed. Surveys had a broad national coverage, represented the same target population, involved a complex sampling scheme designed to represent the target population, were conducted by the same organization (USDA's National Agricultural Statistics Service (NASS)), and collected much of the same information in a similar format. Also, definitions used to summarize and present data were similar across the various years. NAHMS surveys farms with more than 100 head and rely on voluntary participation.

There is a wide body of published research that we reviewed to identify possible productivity differences between gestation stall housing and group pen housing. This portion of the analysis was not concerned with economic feasibility of particular practices, but focused on understanding how alternative systems might impact production performance. This helped guide baseline productivity parameters and sensitivity analysis in the economic models.

A few studies have examined the comparative economics of switching from gestation stalls to group housing. More recently there have been preliminary estimates provided of the cost to become compliant with recent laws requiring producers to provide a minimum amount of square feet to breeding pigs in gestation. Most breeding pigs raised in the United States do not fully comply with these regulations. These preliminary studies are reviewed and summarized to help guide baseline parameters and sensitivity analysis.

Given collection and synthesis of this information, economic models are developed to estimate the expected NPV to a producer from building each evaluated facility. Baseline financials and production records are provided by a case farm that recently invested in new gestation stall and conventional group housing facilities at the same time within the same area. Both facilities use the same genetics and sources for inputs, including feed; which creates an ideal, natural comparison between the two systems. The sensitivity of NPV values to key inputs such as feed and non-feed operating cost differences, interest rates, sow productivity, and up-front building costs are estimated and discussed.

Results

Objective 1: Provide a review and reporting of existing literature and public information to establish baseline values on gestation facility types and housing practices, production performance differences, and cost estimates.

NAHMS swine studies involve the use of questionnaires administered to U.S. swine producers to establish nationally representative estimates of health and management practices—including information about gestation facility type and housing practice. Surveys are voluntary and data was first collected in 1990, followed by studies in 1995, 2000, 2006, and 2012. In 1990 and 1995, the questionnaire did not ask about the gestation phase of production. The repeated nature of NAHMS studies allows examination of health and management practices over time.

Tables 1 and 2 describe changes in facility type for 2000, 2006, and 2012 for the gestation phase of production. The following terms are used to describe facility type. Total confinement is where pigs are raised inside a building with mechanical ventilation and no outside access. Open building with no outside access is defined as any building for housing swine that is open on one or more sides all year (i.e., natural ventilation). The open sides of the building might have a curtain. Open building with outside access is any building that allows access to an outside area (e.g., an uncovered pen).

Table 1. For sites with a gestation phase, percentage of sites by primary facility type used and by study

	Percent Sites							
	Study							
	Swine 1995[1]		Swine 2000		Swine 2006		Swine 2012[2]	
Facility type	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Total confinement	NA		22.4	(1.6)	34.6	(1.9)	38.6	(2.5)
Open building with no outside access	NA		13.9	(1.9)	13.3	(1.5)	25.1	(2.1)
Open building with outside access	NA		45.2	(2.5)	37.3	(2.2)	25.2	(1.8)
Lot with hut or no building	NA		10.3	(1.4)	8.6	(1.2)	6.5	(0.8)
Pasture with hut or no building	NA		8.2	(1.4)	6.2	(1.0)	4.6	(0.7)
Total			100.0		100.0		100.0	

Note: [1] The questionnaire did not ask if there was a gestation phase. In 2000, the question referred to the period from December 1, 1999, through May 31, 2000. In 2006, the question referred to the period from December 1, 2005, through May 31, 2006. [2] Percent sows and gilts farrowed from December 1, 2011, through May 31, 2012. Source: USDA (2017).

Table 2. For sites with a gestation phase, percentage of sows and gilts by facility type used and by study

	Percent Sows and Gilts							
	Study							
	Swine 1995		Swine 2000		Swine 2006		Swine 2012	
Facility Type	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Total confinement	NA		64.2	(3.9)	79.7	(2.9)	76.7	(7.5)
Open building with no outside access	NA		16.4	(4.1)	12.8	(2.7)	20.7	(7.6)
Open building with outside access	NA		14.7	(1.6)	5.6	(0.7)	2.0	(0.4)
Lot with hut or no building	NA		2.8	(0.4)	1.1	(0.2)	0.4	(0.1)
Pasture with hut or no building	NA		1.9	(0.4)	0.8	(0.2)	0.3	(0.1)
Total			100.0		100.0		100.0	

Note: In 1995, the questionnaire did not ask if there was a gestation phase. In 2000, the question referred to the period from December 1, 1999, through May 31, 2000. In 2006, the question referred to the period from December 1, 2005, through May 31, 2006. In 2012, the question referred to the period from December 1, 2011, through May 31, 2012.
Source: USDA (1995, 2001, 2007, 2015).

A higher percentage of operations in 2012 than in 2000 and 2006 housed gestating sows and gilts in an open building with no outside access, suggesting a move toward more naturally ventilated systems for gestating pigs. In 2012, over 97% of all gestating sows and gilts were housed in total confinement or in open buildings with no outside access which was fairly similar to 2006 (over 92%) and not that much more than in 2000 (over 80%).

Tables 3 and 4 shows how gestation facility type differs by size of the breeding herd. A large herd is categorized as 500 or more sows and gilts while a medium herd has between 250 and 499 breeding females and a small herd has fewer than 250 head. Over 98% of large herds housed gestating sows and gilts in total confinement or in buildings with no outside access compared with over 82% and almost 40% of medium and small herds, respectively. Over 40% of small herds housed gestating sows and gilts in open buildings with outdoor access. For large herds, over 99% of all gestating sows and gilts were housed in total confinement or in open buildings with natural ventilation with no outside access which is similar to the 97% of all sows and gilts on all sites. About half of the small herd sows and gilts and almost 81% of the medium herd breeding females were housed in such facilities.

Table 3. Percentage of breeding herds by facility type used for the gestation phase, and by size of herd

	Percent Breeding Herds							
	Herd Size (number sows and gilts)							
	Small (fewer than 250)		Medium (250–499)		Large (500 or more)		All sites	
Facility type	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Total confinement	14.0	(1.4)	43.4	(6.1)	76.8	(5.0)	38.6	(2.5)
Open building with natural ventilation and no outside access	25.7	(1.8)	38.7	(5.8)	21.6	(5.0)	25.1	(2.1)
Open building with outside access	41.7	(2.0)	15.1	(5.8)	1.0	(0.5)	25.2	(1.8)
Lot with hut or no building	11.0	(1.3)	1.7	(1.5)	0.3	(0.3)	6.5	(0.8)
Pasture with hut or no building	7.6	(1.1)	1.1	(0.9)	0.3	(0.3)	4.6	(0.7)
Total	100.0		100.0		100.0		100.0	

Note: Breeding herds on sites that had a gestation phase from December 1, 2011, through May 31, 2012.
Source: USDA (2015).

Table 4. Percentage of sows and gilts by facility type used in the gestation phase, and by size of breeding herd

	Percent Sows and Gilts							
	Herd Size (number sows and gilts)							
	Small (fewer than 250)		Medium (250–499)		Large (500 or more)		All sites	
Facility type	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Total confinement	18.3	(2.4)	44.2	(7.6)	79.4	(8.0)	76.7	(7.5)
Open building with natural ventilation and no outside access	30.6	(2.8)	36.7	(6.7)	20.0	(8.0)	20.7	(7.6)
Open building with outside access	37.6	(2.9)	16.3	(8.5)	0.4	(0.2)	2.0	(0.4)
Lot with hut or no building	9.0	(1.5)	2.1	(1.9)	0.0	(0.0)	0.4	(0.1)
Pasture with hut or no building	4.6	(1.0)	0.7	(0.6)	0.1	(0.1)	0.3	(0.1)
Total	100.0		100.0		100.0		100.0	

Note: Breeding herds on sites that had a gestation phase from December 1, 2011, through May 31, 2012.
Source: USDA (2015).

The NAHMS swine study for the first time in 2012 classified sites, and sows and gilts on those sites, into one of three gestation housing classifications (Tables 5 and 6). These are not meant to be a comprehensive list of possible gestation housing types; rather they are used to provide general categories and within each type differences in practices exist. For example, Johnston and West (2013) indicate that pen configuration, flooring type, feeding system, nutrition program, grouping strategy, timing of grouping, pig flow, husbandry skills, genetics and other factors come together to influence the success of a group housing system.

In 2012, just over three-fourths (75.8%) of all gestating sows and gilts were housed individually. Almost 39% of breeding herds (sites) used individual housing for gestating sows and gilts with over three-fourths (76.6%) of large breeding herds using individual housing. The dimensions of individual stalls commonly used are 22” x 7’ for gilts and 24” x 7’ for sows (Harmon and Levis, 2006). This equates to 12.83 square feet (ft^2) of space and 14 ft^2, respectively. A remaining one-quarter (23.4%) of all gestating sows and gilts spend most of the time in group pens. These group pens generally provide 14 to 20 ft^2 for gilts and 16 to 24 ft^2 for sows with the range in the recommended space requirements due to the type of flooring, i.e., fully or partially slated floor versus a solid floor (Harmon and Levis, 2006). Fifty-one percent of

all breeding herd sites used group housing for the majority of sows and gilts in the gestation phase.

Table 5. Percentage of sows and gilts by type of housing used for sows and gilts in the gestation phase, and by type of facility

	Percent Sows and Gilts							
	Facility Type							
	No outside access		Open building with outside access		Lot or pasture		All sites	
Housing type	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Individual	77.6	(8.9)	14.2	(6.7)	0.4	(0.3)	75.8	(8.6)
Group	22.0	(9.0)	76.3	(6.8)	70.2	(7.6)	23.4	(8.6)
Other	0.4	(0.2)	9.5	(2.7)	29.4	(7.5)	0.8	(0.3)
Total	100.0		100.0		100.0		100.0	

Note: Breeding herds on sites that had a gestation phase from December 1, 2011, through May 31, 2012.
Source: USDA (2015).

Table 6. Percentage of sites by primary type of housing used for the majority of sows and gilts in the gestation phase, and by size of site

	Percent Breeding Herds							
	Herd Size (number sows and gilts)							
	Small (fewer than 250)		Medium (250–499)		Large (500 or more)		All sites	
Housing type	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Individual	14.1	(1.4)	49.3	(6.2)	76.6	(4.9)	38.9	(2.5)
Group	69.2	(1.9)	48.0	(6.2)	22.5	(4.9)	51.0	(2.3)
Other	16.7	(1.6)	2.7	(1.7)	0.9	(0.5)	10.1	(1.1)
Total	100.0		100.0		100.0		100.0	

Note: Breeding herds on sites that had a gestation phase from December 1, 2011, through May 31, 2012.
Source: USDA (2015).

NAHMS swine studies are conducted periodically (generally, every 5–7 years), leading to a series of point-in-time estimates rather than providing any ongoing real-time estimate of gestation facility types and housing practices during the interim periods. The newest NAHMS swine study, originally planned for 2020, was conducted in 2021.[3] The same gestation facility type and housing practice questions that were asked for the 2012 survey were also asked for the 2021 survey.[4] Results are not typically available until several years post data collection. For example, results from the 2012 NAHMS swine study first became publicly available in January 2015 with additional reports being released in February 2016 and August 2017.

The Agricultural Resource Management Survey, or ARMS, is sponsored jointly by USDA's Economic Research Service (ERS) and NASS. It is a multiphase series of interviews with farm operators about their production practices, financial condition, and household well-being. The 1998, 2004, 2009, 2015, and 2020 ARMS versions contained detailed questions on the production and marketing practices, expenses, and revenues associated with U.S. hog production. These are labeled ARMS hogs costs and returns surveys. ARMS collects data from farms with more than 25 head and relies on voluntary participation.

The ARMS surveys collect data on only facility type for gestating gilts and sows. Similar to the NAHMS swine survey this includes enclosed confinement (no outside access, open-sided confinement (no outside access), open confinement (with outside access), quonset or hoop, lean-to, sun-shade, or portable. To our knowledge summary statistics of this gestation facility type information has never been made publicly available. The latest report, using data as current as 2015, only shows the average building capacity for hog production per farm by phase of production, including breeding/gestation (Davis et al., 2022). If the ARMS survey would collect detailed gestation housing information such as individual stall versus group housing, pen size, etc. the data would be valuable for economic analyses because it is a large representative sample of producers and researchers could link gestation housing questions to production and financial outcomes, the use of other practices and inputs, and to farm, enterprise, and operator attributes. Rarely, if ever, are any new questions added to ARMS surveys to maintain survey length and continuity across years.

There are few studies in the United States that examine the comparative effects on productivity of alternative gestation housing systems. Many studies originate from research conducted in Europe rather than in the United States. One must exercise caution when attempting to translate findings generated in Europe to the United States, in part because European agriculture and its regulatory system are considerably different than that of the United States. In addition, studies utilize different methods and procedures, usually consisting of computer models, surveys of experts, or experiments comparing different production practices.

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[3] In light of the substantial market disruptions due to COVID-19, the original timelines for the 2020 NAHMS Swine Study was revised. Data collection from swine operations with 1,000 or more pigs took place between June 2021 and Spring of 2022 and data collection from swine operations with fewer than 1,000 pigs took place between June and July 2021.

[4] The NAHMS Swine Large Enterprise Survey questionnaire is available at https://www.aphis.usda.gov/animal_health/nahms/swine/downloads/swineques/swine2021ques/swine2021large_les-508.pdf.

A large amount of the previous literature comparing breeding herd performance among alternative gestation housing systems has been evaluated in aggregate to determine relationships. These reviews of the literature focus on summarizing published research on production and behavior comparisons between stall housing and group housing systems. Barnett et al. (2001) examined a broad array of studies, examining differences in tethered, stall, conventional indoor group housing, and outdoor group housing. Housing systems did not unequivocally influence reproductive performance. However, underlying factors such as method of feeding, design of facility, stockmanship, diet, genetics, and mating were suggested to impact productivity and animal welfare in any type of facility. McGlone et al. (2004) summarized 35 refereed journal articles that compared sow housing systems focusing on physiology, behavior, performance and health. They concluded that, "Within the restrictions of the methodology adopted in this review, the authors found no clear scientific evidence from comparative studies indicating that stalls or well-managed pens caused consistent and significant signs of stress among pregnant gilts or sows in terms of physiology, behavior, or productivity" (McGlone et al. 2004, p. 115). Rhodes et al. (2005) conducted a thorough and objective review, more than 1,500 peer-reviewed pages, of the scientific evidence relating to the impact on the health and welfare of keeping breeding sows in gestation stalls. No evidence of difference in production performance in sows housed in gestation stalls, compared to sows kept in groups was detected. Since these aforementioned reviews of the literature a number of additional studies have been conducted (Bates, Edwards, and Korthals, 2003; Anil et al., 2005; Hulbert and McGlone, 2006; Seguin, Barney, and Widowski, 2006; Harris et al., 2006; Sorrells et al., 2006; Karlen et al., 2007; Salak-Johnson, 2012; Johnston and Li, 2013; Ison et al., 2014; Knox et al., 2014; Kim et al., 2016; Salak-Johnson, 2017). However, there have not been general findings in support of or against the performance hierarchy of alternative gestation housing systems. All systems have strengths and weaknesses and management of the system is critical and the science does not emphatically support one system over another (Johnson, 2007). Buhr (2010) reporting on findings of an open-ended telephone survey found that there were significant learning curves and that the risk of catastrophic problems in group gestation pen housing was greater than in gestations stalls because of the inability to manage sows individually and adjust management and labor to achieve comparable production results.

The extent to which acceptable economic performance can be realized in alternative housing systems for gestating sows depends on the level of performance which can be achieved in a given system relative to the cost requirement (Edwards, 2008). Maximizing breeding herd performance is an obvious goal of any producer and any housing system that has a negative impact on performance will likely not be widely adopted. Relatively small differences in performance are of practical and economic importance and can significantly influence production costs.

A few studies in the United States have examined the comparative economics of switching from gestation stalls to group housing. Lammers et al. (2008) compared the construction and operating costs of conventional individual gestation stall facilities to group pen housing in hoop barns. Projected budgets based on surveyed construction costs of stall facilities and actual costs of research hoop facility at Iowa State University were used to compare costs per weaned pig. At equal proficiency, variable costs were $24.82 per weaned pig produced in stalls and $25.14 per weaned pig produced in the group pen housing hoop facility.

Fixed costs were $9.16 per weaned pig in the stall facility and $7.70 per weaned pig for the hoop facility due primarily to the 32% higher construction cost per gestating sow space for individual confinement stalls compared to group housing in hoop barns. Total cost per weaned pig produced in the conventional stall facility was estimated at $33.98 compared to a total cost for the hoop facility of $32.84 per pig weaned. However, as Buhr (2010, pg. 13) notes, "it's highly unlikely hoop facilities will replace existing commercial facilities." This is evidenced by gestation facility types and housing practices currently being used in the United States.

Buhr (2010) provided an economic analysis of the economic impact of transitioning from gestation stall housing to group pen housing under a regulatory mandate. While somewhat germane to our study, their scenario assumes that farms are required to either retrofit or rebuild facilities to accommodate group pens. This leads to estimating aggregate industry economic impacts. The authors found that under the most likely scenario, industry losses would range between $1.87 billion if all barns were retrofitted and $3.24 billion if new barns needed to be built. This would equate to a 74% to 129% decrease in industry NPV, respectively.

Seibert and Norwood (2011) compared a confinement-stall system, confinement pen system, confinement enhanced system, and a pasture-shelter system using a farrow to finish budget. All that differed in the confinement-stall system versus the confinement pen system was the gestation phase. The projected production cost of the confinement-stall system was $119.25 per finished pig while the projected cost of a new confinement pen system was $128.79 per finished pig. The analysis assumed sow productivity was unchanged in the pen versus the stall system and new construction costs of a stall versus pen system were estimated to be roughly the same. Fixed and labor costs were increased in the group pen system to account for fact that it could only accommodate 18% fewer sows.

The Sow-Housing Conversion Model (Pork Checkoff, 2013) is an Excel-based analysis tool that can be used to compare sow-farm financial results between an existing farm and a converted farm. The model considers the additional investment (labor, building materials and equipment) needed for the conversion along with any down-time costs, and changes to the size of the sow herd, space allowance provided per sow, diets, and production flow. The example shows a cash flow cost per pig of $32.74 for the existing facility and $38.30 for a converted facility.

The Sow Housing Options Tool (Michigan State University Extension, 2016) is designed to assist producers in evaluating gestation housing options. The Excel-based model shows the impact on the cost per pig weaned from the various investments, operating cost and productivity assumptions across the sow housing system options being evaluated. It is noted that system size, geographic location, local supply and demand, and many other factors create potentially significant differences between various housing systems. Using the 1,200 sow example farm base assumptions in the worksheet and comparing an existing conventional stall system to building all new and producing the same number of pigs shows between a $3.50 and $4.85 increase in the total cost per weaned pig depending on the type of group housing feeding system.

This aforementioned seminal research on the economic impacts of switching from gestation stalls to group pen housing is approximately ten years old or older. Because the estimates are for a period prior to the renewed gestation housing debate and before the recent

inflationary pressures and record high in input costs, analysis of group housing systems needs to be updated and expanded.

Prior to implementation, a few economic studies were conducted to estimate the potential impacts of Proposition 12 on swine producers. Lee, Sexton, and Sumner (2021) indicate about 8% to 9% of North American sow housing, enough for about 0.7 million sows, would need to meet Proposition 12 standards. They say that because the adjustment would be less costly for them, the operations that convert to meet Proposition 12 standards will be among those that already have group housing. Combining one-time building costs and ongoing feed and other operating costs the study calculates a 15% increase in costs per weaned pig for California-compliant operations. They use an average cost of about $33 per weaned pig to give a cost increase at the farrowing operation of approximately $5 per weaned pig. In 2022 weaned pig costs of production of about $44 per pig[5] a 15% total cost increase would equate to a cost increase at the farrowing operation of nearly $7 per weaned pig.

In order to comply with Proposition 12, RaboResearch (2021) estimates that at least 15% of U.S. producers would need to convert to the new production directive. For producers already housing sows in group pens, the transition would require additional space or a reduction in the number of sows. A producer would require 20% to 25% more barn space or they need to reduce their stocking densities to accommodate the change in the industry standard of 18 ft^2 to 20 ft^2 per sow to compliant spacing of 24 ft^2 per sow. It was emphasized that the practicalities of retrofitting a barn are challenging, and producers will likely opt to construct new barns to maintain pig flows. However, the ability to add capacity is influenced by availability of land and permits. New barn costs will vary by producer and are driven by the cost of materials, technology, and the level of functionality. The author suggests an average barn might cost $1,600 to $2,500 per sow, or $3.0 million to $4.5 million total while some Proposition 12 compliant barns are averaging as much as $3,400 per sow. This study also warns that producers that have not already moved to group housing or only recently converted their operations could find conversion costs prohibitive.

In October 2021, Compeer Financial provided estimates on the financial costs of Proposition 12. Regarding adjustments to sow housing, they indicate pork producers generally have three options to consider: reducing the size of sow herd, reconstructing or reconfigure existing facilities, or building new construction. If there is no change in the gestation facility size they estimate a 25% reduction in the sow herd, a 6% reduction in the farrowing rate, and a 0.67 pig reduction in pigs weaned per sow which equates to a total cost of $17.59 per pig. If square footage is added to an existing facility to keep sow numbers stable they estimate it would cost between $1,500 and $2,150 per gestation space depending on standard gestation housing versus free access stalls. This is an increase over new construction due to removal and disposal costs with 74% of 75% of the cost being due to the additional square footage needed. Additional production cost considerations include an increase in non-productive sow days as farrowing rate would be expected to drop 6% to 10%, additional feed costs for non-productive sow days could be between $0.13 and $0.22 per pig, and with lower total pigs born per sow (0.65 to 1.0 pigs) this could add $2.46 to $3.79 per pig to the total cost. If mortality increases in the sow herd by 3% to 5% this would increase cost per pig by $0.30 to $0.50. The total

[5] http://www2.econ.iastate.edu/estimated-returns/.

estimated increase cost per pig from production measure changes ranges from $2.89 to $4.51 per pig.

Much of the previous work focuses on comparing the costs of confinement systems to stylized systems (Seibert and Norwood, 2011) or hoop barns (Lammers et al., 2008) or converting existing gestation stall facilities to group housing (Buhr, 2010; Pork Checkoff, 2013). Evaluating the financial implications of these decisions has also been a focus (Buhr, 2010; Michigan State University, 2013; Pork Checkoff, 2013). This study differs from previous work because we take the approach of estimating the impact of new barn construction across three systems, we do not consider converting existing structures. This allows us to evaluate the difference between investing in gestation stall housing, conventional group housing, or group housing with increased square feet per sow. We also consider the space requirements for group housing with increased square feet per sow and how that impacts the number of sows on an operation if the same building footprint is desired. This approach allows us to evaluate the cash flow and profitability impacts of investment decisions to identify how, or if, economies of size impact decisions as well as the economic factors and sow productivity parameters that may impact these decisions.

Objective 2: Develop economic models to estimate the net present value (NPV) to a producer from investing in new gestation stall housing versus conventional group housing versus group housing with increased square feet per sow.

Deciding to invest in new facility construction is a multi-year decision. Determining the economic implications of this decision is not as simple as multiplying one year of revenues and expenses by the number of years of the investment. Rather, several economic and productivity factors must be considered, such as interest rates, marginal tax rates, sow mortality, farrowing rate, feed efficiency, and how these factors impact revenues and expenses, among other factors. Because this is a multi-year decision, we must also consider that a dollar today is not worth the same value as a dollar in the future, as evidenced by the inflation rate increasing by 8.5% from July 2021 to July 2022 (U.S. Bureau of Labor Statistics, 2022). And although inflation slowed to 3.0% in June 2023, it was still above the Federal Reserve's 2.0% target rate. In July 2023, the Federal Reserve raised interest rates for the eleventh time in the past seventeen months, to its highest level since 2001, as it continues to fight persistent inflation in the U.S. economy (Associated Press, 2023).

To capture these aspects, a multi-year NPV or capital budget analysis is completed. A NPV allows us to analyze the impact of investing in an asset today and the impact of the cash flows it generates over the life of the investment. NPV analysis includes multi-year budgeting, discounting future cash flows generated from the investment to today's value (time=0) and comparing the NPV of those discounted future cash flows to the investment made today (Kay, Edwards, and Duffy, 2008; Olson, 2011; Barry and Ellinger, 2012).

An investment in a capital asset should be made if the NPV is greater than zero. This means that the return on the investment is greater than the cost of capital. Or another interpretation is the producer could pay more for the investment and still achieve a rate of return equal to the discount rate used in calculating the NPV. If NPV=0, the producer would be indifferent in making the investment. If an investment results in a negative NPV, the investment

should not be made since the producer will not recover the investment costs through generated revenues and expenses over the life of the asset (Kay, Edwards, and Duffy, 2008; Olson, 2011; Barry and Ellinger, 2012).

The NPV calculation is defined as:

$$(1)\ NPV = -Investment_{t=0} + \frac{\sum_{t=1}^{T=15} Cash\ Inflows_t - Cash\ Outflows_t}{(1+WACC)^t},$$

where *Investment* is the investment cost of a new farrow to wean facility, *Cash Inflows*$_t$ are revenues generated from farrow to wean production including weaned pig sales/transfers and cull sow sales at time *t*, *Cash Outflows* includes cash operating expenses, loan payments, and fixed expenses from the farrow to wean operation at time *t,* and the weighted average cost of capital (*WACC)* is the discount rate.

The discount rate used can have a large impact on NPV calculations. Because the asset analyzed will generate income and expenses, we need to use a discount rate that considers the after-tax return to the capital asset. The WACC is calculated using a farm's marginal tax rate, solvency measures from the farm's balance sheet, as well as the cost of equity and the cost of debt. Therefore the discount rate is not just the cost of debt, but includes other economic factors that affect the investment decision.

The WACC is calculated as:

$$(2)\ WACC = \left(i_e + \frac{E}{A}\right) + \left[\left(i_d + \frac{D}{A}\right) * (1 - Tax\ Rate)\right],$$

where i_e is the cost of equity, $\frac{E}{A}$ is the equity-to-asset ratio, i_d is the cost of debt or the interest rate, $\frac{D}{A}$ is the solvency rate or debt-to-asset ratio, and *Tax Rate* is the marginal tax rate. The cost of equity, $\left(i_e + \frac{E}{A}\right)$, captures the opportunity cost of equity for the farm. Or, one can think of it as the highest rate of return the farm could be earning in an alternative investment with similar risk. The after-tax cost of debt, $\left(i_d + \frac{D}{A}\right) * (1 - Tax\ Rate)$, considers the implications of tax deductions for interest expense based on the solvency level of the farm. It is important to note that each of these economic parameters are specific to the farm included in the analysis. This provides full information to the decision maker regarding the after-tax implications of this investment over time (Barry and Ellinger, 2012).

Microsoft Excel® was used to create an NPV to analyze new barn construction costs for three large (6,400 sow) gestation housing systems including: (1) stalls, (2) conventional group housing, (i.e. 20 ft^2 per sow),[6] and (3) group housing with increased square feet per sow. The latter case would be consistent with laws requiring farmers to provide a minimum amount of square feet (i.e., 24 ft^2) to breeding pigs in gestation. The first step of this analysis was to compile data associated with each housing system, which includes the investment cost of the

[6] "Business Practices - Animal Husbandry" in the S*wine Packer Marketing Contract Summary – National Other Provisions* provides definitions and contract terms for sow housing, https://www.ams.usda.gov/sites/default/files/media/SCLCSROP.pdf.

barn, operating expenses, fixed expenses, and productivity parameters. These components were collected from a case farm, published studies, as well as industry estimates obtained through personal interviews. It is important to note that any individual cost item may become dated due to inflation, deflation, or other factors. However, the primary focus of this analysis is not a comparison of the actual cost of production, although we estimate that, but rather a comparison of the relative difference in costs and returns of producing weaned pigs using different gestation housing systems.

The case farm used in this analysis was selected because they constructed new gestation stall and conventional group housing facilities at the same time within the same area. Both facilities use the same genetics and sources for inputs, including feed; which creates an ideal, natural comparison between the two systems. We greatly appreciate the willingness of this farm to share their data. The base scenario assumptions for the NPV analysis were generated using a 3-year average (2019-2021) of operating expenses and sow performance metrics provided by the case farm. Fixed expenses were calculated based on the assumptions for new barn construction. The calculated fixed expenses match closely with the expenses provided by the case farm. Price indices and other available information were utilized to update values to include current (2022 and in some cases 2023) costs.

Due to the lack of data available for group housing with increased square feet per sow because of the newness of the systems, excluding often quoted estimates for fixed costs, the conventional group housing parameters were used as the initial base scenario for group housing with increased square feet per sow. The sensitivity analysis considers various changes in productivity parameters and operating expenses associated with increasing the square feet per sow in group housing. Each of the assumptions are described in further detail in the subsequent sections.

Investment costs and financing options

Investment costs for new barn construction varies by the gestation housing type used. In addition, they will vary across producer because of the cost of materials used, technology, and the level of functionality. RaboResearch (2021) reported construction costs for an average barn at $1,600 to $2,500 per sow. Compeer Financial (2021) reports an average cost of $2,700 to $3,100 per sow for new pen gestation. RaboResearch (2021) indicates some new Proposition 12 compliant barns are averaging as much as $3,400 per sow while Compeer (2021) is higher at $3,600 to $4,000 per sow. Lee, Sexton, and Sumner (2021), based on data from industry, expect facility costs to rise by about 20% per sow to achieve an increase in space per sow from 20 to 24 square feet. They also indicated that new feeding and other innovations would likely add another 5% to capital costs. Interviews with building contractors and producers considering new construction for group housing with increased square feet per sow in 2022 confirmed that construction costs were within the range of $3,400 to $4,000 per sow with the expectation that these costs may continue to rise with increased building material and labor construction costs. These increases occurred with building material prices 17% higher when comparing 2022 and the first five months of 2023 with 2021, according to the USDA National Agricultural Statistics Service prices paid index. Similarly, capital recovery of machinery and equipment is up 17% from 2021 to 2022 according to the USDA Economic Research Service Hogs, Farrow-Feeder:

Production Costs and Returns. Capital recovery of machinery and equipment is an estimate of the cost of replacing the capital investment in machinery and equipment that is used up in the annual production process, plus interest that the remaining capital could have earned in an alternative use.

New barn construction costs per sow are assumed to include all costs associated with prepping the building site, materials to construct the barn, as well as the equipment inside the structure, which includes: stalls (for farrowing), pens and free access areas. New construction for a gestation stall facility is assumed to be $3,155 per sow with a total investment of $20.02 million (M) for a 6,400 sow operation (Table 7). According to Buhr (2010), for conventional group housing, i.e. 20 ft^2 per sow, approximately 20% more gestation building square footage is required to accommodate the same sows as in a stall system which represents approximately a 10% increase in the overall gestation and farrowing project cost which could be higher due to increased maintenance and management costs. This follows from the elimination of more expensive stalls and feed pans in the pen facility causing the proportion of costs allocated to the building portion of the gestation barn to increase while the equipment costs decrease (Buhr, 2010). New construction for a 6,400 sow conventional group housing facility is assumed to be $3,622 per sow for a total investment of $23.18M. Previous work has emphasized that increasing the square feet per sow in group housing will require the producer to build a larger barn to maintain their current capacity or decrease their sow herd by 20% to 25% (Lee, Sexton, and Sumner, 2021; RaboResearch, 2021; Compeer Financial, 2021). We assume that new construction for group housing with increased square feet per sow is $4,499 per sow. This per sow investment cost is applied to two systems: a 4,800 and 6,400 sow unit with the former following from a 25% decrease in herd size to maintain the same building footprint while adhering to per sow space requirements. Using the same per sow construction costs, results in a total investment of $21.60M and $28.79M for the 4,800 and 6,400 sow units, respectively.

The level and type of financing impacts the investment cost reported in year 0 of the NPV. Specifically, if a farm puts 20% cash down payment on the investment, the initial investment in year 0 of the NPV is that cash payment (eg. -*Investment* in equation (1) = 20% * Total Investment). The remaining value of the investment is captured in the NPV through the principal payments associated with the loan. Most often loans use an equal total payment, so the dollar amount paid to the bank remains constant over the life of the loan. However, the principal and interest payments vary year by year. This is similar to any home mortgage payment. These economic parameters have important implications for a producer's after-tax cash flows. In particular, the interest expense on the loan is a tax deduction, which has the potential to decrease the farm's tax liability over time. The interest expense deduction changes annually based on the decreased loan balance associated with the principal payments.

Data collected through interviews with agricultural lenders confirm that the average loan length for new construction of a large sow gestation unit is 10-15 years, with 15 years commonly used for a facility with 6,400 sows. Additionally, the depreciation schedule used for a swine facility is 15 years, using straight-line depreciation with a 10% salvage value (IRS, 2021; Buhr, 2010). This allows the loan time period to match the depreciation schedule used for tax purposes for the facility. We acknowledge that the barn will be used past the 15 years, however, we are following guidance recommended through interviews with agricultural lenders.

Table 7. Facility construction costs and economic assumptions by housing system

Housing system	Stalls	Group Housing	Group Housing Increased ft^2 per Sow‡	
Number of Sows	6,400	6,400	4,800	6,400
Total facility investment, $/sow	3,155	3,622	4,499	4,499
Total facility investment, $	20,019,200	23,180,800	21,595,200	28,793,600
Salvage value of facility	2,019,000	2,318,080	2,159,520	2,879,360
Annual depreciation, $	1,211,520	1,390,848	1,295,712	1,727,616
Loan Payment Information				
Cash down payment, $	4,038,400	4,636,160	4,319,040	5,758,720
Annual loan payment*, $	1,773,578	2,036,102	1,896,830	2,529,106

Economic Assumptions	Value	Source
Salvage value of facility	10%	Buhr, 2010
Depreciable life of facility	15 years	Compeer Financial, 2022; IRS, 2021
Length of loan	15 years	Compeer Financial, 2022
Loan interest rate	7%	Federal Reserve Bank of Chicago, 2023
Loan down payment	20%	Compeer Financial, 2022

Note: * Equal total annual loan payment assumes a 15 year loan with 20% down at a 5% interest rate. ‡ Base scenario assumption is that conventional group housing and group housing with increased square feet per sow have the same operating expenses and sow productivity, all that differs is the facility investment cost.

New barn construction is assumed to be financed through a 15 year loan using traditional agricultural lending options. Historically, producers have provided a down payment of 15% to 25% of the total cost of the investment. We assume a 15 year loan with 20% down payment and the remaining 80% of the investment financed with a 7% interest rate (Federal Reserve Bank of Chicago, 2023). Total facility investment costs, annual loan payments, depreciation estimates, and economic assumptions are calculated and reported in Table 7.

Production parameters

Costs per unit and net returns in pig production are highly dependent on production levels. This includes the number of sows, weaned pigs per litter, weaned pigs per sow per year, culling rate of sows, sow mortality, and farrowing rate. The case farm provided 3 years of Pig Computerized Health and Management Program, or PigCHAMP, records for their gestation stall and conventional group housing systems. These records were compared to other publicly reported ranges and were found to be in line with those values and used as inputs for our baseline scenario. Productivity parameters for conventional group housing were applied to the group housing with increased square feet per sow base scenario. The only change with the group housing with increased square feet per sow base scenario is the number of sows in the gestation facility. Again, the base scenario assumes the equivalent sized barn, which resulted in a lower number of sows. We also included a 6,400 sow group housing with increased square

feet per sow facility at the investment rate of the 4,800 sow unit to provide a direct comparison of the additional capital investment needed to remain at a constant 6,400 sow level.

Productivity assumptions for the base scenario across housing systems are presented in Table 8. The most notable differences between productivity and housing system includes pre-weaning mortality which increases from 15.80% to 19.87% between gestation stall and conventional group housing. Additionally, differences in sow mortality and culling rates are observed between gestation stall and conventional group housing. Again, due to the lack of data available regarding sow productivity in group housing with increased square feet per sow, we assumed that the base scenario productivity parameters would be equivalent to conventional group housing. The group housing with increased square feet per sow productivity parameters will be adjusted in the sensitivity analysis completed in Objective 3 to illustrate the impacts of potential changes on the NPV.

Table 8. Production parameters by housing system

Housing system	Stalls	Group Housing	Group Housing Increased ft^2 per Sow‡
Number of sows	6,400	6,400	4,800	6,400
Liveborn pigs per sow per year	33.90	31.83	31.83	31.83
Weaned pigs per sow per year	28.50	25.53	25.53	25.53
Weaned pigs per litter	11.70	11.17	11.17	11.17
Pre-weaning mortality, %	15.80	19.87	19.87	19.87
Farrowing rate, %	91	90	90	90
Sow mortality, %	7	11	11	11
Culling rate, %	46	43	43	43
Cull sow weight, cwt	5.00	5.00	5.00	5.00

Source: 3-year averages from the case farm's PigCHAMP records, 2019-2021. ‡ Productivity parameters for conventional group housing were applied to the group housing with increased square feet per sow base scenario.

Cash inflows (revenues)

Cash inflows include revenue generated from the farrow to wean enterprise. This includes cull sow sales in addition to the sale (or transfer) of weaned pigs. The number of culled sows are estimated using culling rates reported from the case farm and validated using publicly reported averages and published studies. We use an average cull sales price of $52.51 per hundredweight (cwt), which is based on the 2019 to 2022 average for 450 to 550 pound national negotiated sows provided by the USDA-AMS Weekly National Direct Swine Report (LM_HG214). A cull sow weight of 500 pounds, or 5.00 cwt, is used. Sales price and cull sow weight remains constant across housing systems and over time. The number of culled sows varies based on the productivity parameters reported in Table 8 by housing system.

Weaned pig sales, or the number for transfer, are calculated based on the number of pigs weaned per sow per year and the number of sows for each housing system, as reported in Table 8. We use the 2019 to 2022 composite weighted average (formula and cash) early weaned pigs 10-12 pound basis price of $47.25 per head provided by the USDA-AMS National

Direct Delivered Feeder Pig Report.[7] Estimated revenues or cash inflows are presented in Table 9. Since we assume these are representative of long-run prices, these inflows remain constant over the 15 years of the NPV.

Cash inflows decrease by $2.11M for the 4,800 sow group housing with increased square feet per sow system compared to the 6,400 sow group housing with increased square feet per sow unit. This is due to the decreased number of sows on the operation, which decreases the number of weaned pigs, and ultimately the revenue generated on the farm. The conventional group housing system generates $948,537 less in cash inflows than stall gestation housing, again due to decreased sow productivity measures, as outlined in Table 8.

Table 9. Cash inflow assumptions by housing system and farm size, base scenario

Item	Stalls	Group Housing	Group Housing Increasing ft^2 per Sow‡	
Number of sows	6,400	6,400	4,800	6,400
Cull sales				
Number of culled sows	2,944	2,752	2,064	2,752
Cull sales, $/cwt	52.51	52.51	52.51	52.51
Cull weight, cwt	5.00	5.00	5.00	5.00
Annual cull sales, $	772,947	722,538	541,903	722,538
Weaned pig sales				
Pigs weaned per sow per year	28.50	25.53	25.53	25.53
Weaned pig price, $/pig	47.25	47.25	47.25	47.25
Annual weaned pig sales, $	8,618,400	7,720,272	5,790,204	7,720,272
TOTAL CASH INFLOWS	**9,391,347**	**8,442,810**	**6,332,107**	**8,442,810**

Notes: ‡ Base scenario assumption is that conventional group housing and group housing with increased square feet per sow have the same operating expenses and sow productivity, all that differs is the facility investment cost.

Cash outflows (operating and fixed expenses)

Cash outflows include operating and fixed expenses associated with sow farm operations. The case farm provided three years of operating expenses for their gestation stall and conventional group housing facilities. We compared these expenses with information we gathered from other farms through personal interviews and data we collected from industry calculations. Price indices and other available information were utilized to update values to include current costs (USDA-NASS, 2023). Differences by operating expense category across housing system are a result of the information provided by the case farm and may not be representative of all systems. It is important to note that data provided from the case farm (with updates to include current prices) showed notable cost volatility, and we assume that these costs are representative of long-run averages.

Fixed expenses are categorized as non-cash and cash expenses. This distinction is important because it impacts the after-tax net cash flows and the cost of production differently.

[7] March-September 2020 data were omitted from the average due to COVID-19 disruptions.

Let's first discuss the after-tax net cash flows. The key distinction is the word cash, which means we do not include depreciation in the after-tax net cash flow calculation, since it is a non-cash expense. Rather the depreciation expense will be used for the income tax calculation. The after-tax cash flows are calculated as:

$$(3)\ After-tax\ cash\ flows_t = Cash\ Inflows_t - Cash\ Operating\ Expenses_t - Cash\ Fixed\ Expenses_t,$$

where *Cash Inflows* are the revenues generated in year *t* as reported in Table 9. Annual *Cash Operating Expenses* include GDU costs, feed, veterinary (including breeding fees), trucking, utilities, supplies, hired labor, manure management, and miscellaneous expenses, and annual *Cash Fixed Expenses* include principal payments, interest expense payments, farm insurance, and income taxes.

Earlier in the report we emphasized the importance of capturing the after-tax cost of this investment. This is due to the reality that a producer must evaluate this investment decision considering tax implications, which includes a depreciation and interest expense deduction. Annual income taxes are calculated following:

$$(4)\quad Income\ Taxes_t = (Cash\ Inflows_t - Operating\ Expenses_t - Depreciation_t - Interest\ Expense_t - Farm\ Insurance_t) * Tax\ rate.$$

Equation (4) does not include principal payments. Income tax policy does not allow for principal payments to be used as a tax deduction, only interest expense can be deducted. Rather, depreciation is included in equation (4), which is a non-cash tax deduction (IRS, 2021). The depreciation timeline normally matches up with the loan schedule time period, which results in similar estimates between total principal paid and depreciation expense, on an annual basis. If the principal payments and depreciation expense were both included in this calculation, we would be double counting. This distinction does have implications for our estimates and will continue to be referenced throughout the report.

The NPV analysis evaluates the cash flow of the investment over time, which differs from the cost of production, which is looking for a break-even price to generate profit on an annual basis. This distinction is demonstrated with the estimated annual operating and fixed expenses reported in Table 10. Total operating expenses are reported for each expense category and housing system. The operating expenses are a function of the number of sows and subsequent weaned pigs per sow per year. For example, the feed cost is lower for the group housing with increased square feet per sow system that has 4,800 sows. This is due to the smaller herd size for this specific system, it is not due to feed savings via lower costs or efficiency. Similarly, you will notice that the conventional group housing and group housing with increased square feet per sow system for 6,400 sows have the same feed cost. This is because the base scenario feed cost is assumed the same between the two systems and they have the same number of sows.

The differences across these housing systems occurs with the fixed expenses. Annual depreciation is a function of the total investment cost, as reported in Table 7. Facility principal and interest payments change year to year, which impacts income taxes. For the purposes of

this summary table, we report the 15-year average for each of those expenses. The annual depreciation expense is reported in Table 10 with a note below the table that it is not included as a cash outflow, but the depreciation is used to calculate the income taxes. As reported, income taxes vary by housing system. Gestation stall housing reports the highest income tax level due to positive net cash flows on an annual basis. That does not hold for the other housing systems across all years. Lower income tax payments indicate a series of negative annual net cash flows which results in an income tax payment that is zero. The group housing with increased square feet per sow barns experienced negative net cash flows for the majority of the years of the NPV.

Recognizing that cash flows and profit are not equal is an important part of this analysis. However, producers use their cost of production to make decisions on their farm. We convert the annual total operating and fixed expenses to a dollar per weaned pig per year to determine if the projected selling prices with this investment allow a producer to break-even in the base scenario.

As a reminder, the principal payments are not included in the cost of production estimate. Rather, depreciation expense is included as a non-cash expense. The reasoning behind this difference is depreciation captures the wear and tear on the asset, so including this in the cost of production ensures you are generating enough revenue to replace equipment and infrastructure as needed. Principal payments and income taxes are not included in the cost of production estimates; however, we do include them in Table 11 for a comparison. We include notes below the table describing why they are not included in the cost of production calculation. If depreciation and principal payments were both included in the cost of production calculation, we would be double counting.

The cost of production is calculated at the operating and fixed expense level and added together for a total cost of production estimate in the last row of Table 11. The operating expense cost of production is $31.64 per weaned pig in the gestation stall system. This increases to $36.56 per weaned pig in conventional group housing or group housing with increased square feet per sow. Again, this increase was determined using expense data provided from the case farm (with updates to include current prices) and assuming conventional group housing and group housing with increased square feet per sow was the same. The fixed expense cost of production varies across all four housing systems. This is due to the differing investment levels and the associated principal and interest payments.

The fixed expenses range from $11.09 per weaned pig for gestation stall housing up to $17.28 per weaned pig for the 6,400 sow group housing with increased square feet per sow facility. In the long run, all fixed expenses become variable, but in the short run, the farm manager needs to ensure they can cover their operating and fixed expenses on an annual basis to generate profit. If we compare the total cost of production for each housing system to the selling price for weaned pigs, $47.25 per pig, we observe that only the gestation stall housing system generates profit at $4.52 per weaned pig. This is in line with historical estimates for farrow to wean production. The Iowa State University Estimated Livestock Returns for farrow to wean production reports a profit of $5.06 per weaned pig for the January 2001 through June 2023 period.[8] All other housing systems generate a negative profit. Specifically, the 6,400

[8] http://www2.econ.iastate.edu/estimated-returns/.

conventional group housing loses $3.34 per weaned pig, the 4,800 sow group housing with increased square feet per sow system loses $5.07 per weaned pig and the 6,400 sow group housing with increased square feet per sow system loses $6.59 per weaned pig. A producer's goal is to generate profit and breaking even does not result in any positive profit. Additionally, we have not discounted any of these expenses within the context of the NPV, these estimates are tied to the specific investment and assumptions associated with the housing system. As we move forward with the analysis, a producer is making two decisions regarding the investment:

1. Will the investment cash flow over time?
2. Will the farm generate positive profit on an annual basis?

The NPV analysis will be used to answer question 1. The annual operating and fixed expenses or cost of production compared to the selling price received will answer question 2.

Table 10. Estimated annual operating and fixed expenses by housing system

Item	Stalls	Group Housing	Group Housing Increased ft² per Sow‡	
Number of Sows	6,400	6,400	4,800	6,400
Operating Expenses				
GDU	773,828	889,154	666,866	889,154
Feed	2,342,759	2,461,264	1,845,948	2,461,264
Veterinary (Animal Health)	282,152	395,139	296,355	395,139
Breeding/Genetic	174,732	175,874	131,906	175,874
Labor	1,007,217	977,892	733,419	977,892
Utilities	257,192	232,584	174,438	232,584
Trucking costs (cull sales & weaned pigs)	575,592	524,464	393,348	524,464
Repairs & Maintenance	63,595	73,507	55,130	73,507
Manure management	206,718	130,712	98,034	130,712
Supplies	61,801	90,422	67,817	90,422
Misc. Exp	25,099	22,483	16,863	22,483
Fixed Expenses				
Facility & Equipment Depreciation&	1,211,520	1,390,848	1,295,712	1,727,616
Facility Principal Payments*	1,076,907	1,236,309	1,151,744	1,535,659
Facility Interest Payments*	696,672	799,793	745,085.5	993,447
Insurance	114,365	102,447	76,835	102,447
Income Taxes*	606,452	141,003	68,015	90,686
TOTAL CASH OUTFLOWS*	**8,262,080**	**8,253,049**	**6,521,802**	**8,695,736**

Note: ‡ Base scenario assumption is that conventional group housing and group housing with increased square feet per sow have the same operating expenses and sow productivity, all that differs is the facility investment cost.
& Not included in cash outflow calculation, but used to calculate income taxes; * Average over 15 years since varies year by year.

Table 11: Estimated operating and fixed expenses by housing system, dollars per weaned pig and per sow

Housing system	Stalls		Group Housing		Group Housing Increased ft² per Sow‡			
Number of Sows	6,400		6,400		4,800		6,400	
	$/weaned pig	$/sow	$/weaned pig	$/sow	$/weaned pig	$/sow	$/weaned pig	$/sow
Operating Expenses								
GDU	4.24	120.91	5.44	138.93	5.44	138.93	5.44	138.93
Feed	12.84	366.06	15.06	384.57	15.06	384.57	15.06	384.57
Veterinary	1.55	44.09	2.42	61.74	2.42	61.74	2.42	61.74
Breeding/Genetics	0.96	27.30	1.08	27.48	1.08	27.48	1.08	27.48
Labor	5.52	157.38	5.98	152.80	5.98	52.80	5.98	152.80
Utilities	1.41	29.93	1.42	36.34	1.42	26.13	1.42	36.34
Trucking costs – cull sales & weaned pigs	3.16	89.94	3.21	81.95	3.21	81.95	3.21	81.95
Repairs & Maintenance	0.35	9.94	0.45	11.49	0.45	11.49	0.45	11.49
Manure management	1.13	32.30	0.80	20.42	0.80	20.42	0.80	20.42
Supplies	0.34	9.66	0.55	14.13	0.55	14.13	0.55	14.13
Misc. Exp	0.14	3.92	0.14	3.51	0.14	3.51	0.14	3.51
Fixed expenses								
Depreciation	6.64	189.30	8.51	217.32	10.57	269.94	10.57	269.94
Facility Principal Payments*	5.90	168.27	7.57	193.17	7.05	239.95	9.40	239.95
Facility Interest Payments*	3.84	108.85	4.89	124.97	4.56	155.23	6.08	155.23
Insurance	0.63	17.87	0.63	16.01	0.63	16.01	0.63	16.01
Cost of Production								
Operating Expenses	31.64	901.67	36.56	933.36	36.56	933.36	36.56	933.36
Fixed Expenses**	11.09	316.02	14.03	358.29	15.76	441.17	17.28	441.17
Total Cost of Production	**42.73**	**1,217.69**	**50.59**	**1,291.65**	**52.32**	**1,374.53**	**53.84**	**1,374.53**

Note: ‡ Base scenario assumption is that conventional group housing and group housing with increased square feet per sow have the same operating expenses and sow productivity, all that differs is the facility investment cost; * Average over 15 years since varies year by year; ** Does not include principal payments nor income taxes.

Up to this point, all of the information provided is an annual value or on average across the 15 years of the investment. To implement the NPV, we must discount each annual value to today's dollars. We must include the discount rate, which will bring future after-tax cash flows to today's value. We use the weighted average cost of capital (WACC) as our discount rate, as described in equation 2. This allows us to consider the after-tax cost of capital. The economic assumptions used as the foundation of the WACC calculation are included in Table 12. We assume a 7% interest rate for the cost of debt, which is close to the current rate for farm real estate loans (7.14%) reported by the Federal Reserve Bank of Chicago (2023) for the first quarter of 2023. The cost of equity was included at 8%, long-run returns on stock market investments are often reported at 7% to 10%, with volatile markets, we assumed 8% for this analysis. The solvency of a farm will be a function of their current debt load—we assumed a farm considering this investment would be in good financial standing with their debt-to-asset ratio at 45%. This means that a creditor owns 45% of the capital assets on the farm, while the remaining 55% is owned by the farmer. Finally, the marginal tax rate was collected from the IRS (2021) assuming the average income generated from a 6,400 sow unit. When we apply these assumptions to the WACC equation (3), the resulting discount rate is 6.4%.

Table 12. Economic assumptions for WACC discount rate

WACC variables	Unit	Source
Cost of debt	7%	Federal Reserve Bank of Chicago, 2023
Cost of equity	8%	Author's assumption
Debt-to-asset ratio	45%	Author's assumption
Equity-to-asset ratio	55%	Author's assumption
Marginal tax rate	35%	IRS, 2021
Estimated WACC	**6.4%**	

Estimated NPV

Four NPV analyses were estimated in Microsoft Excel® using the base scenario assumptions reported in Tables 7-12. The NPV results are presented in Table 13, which includes the summation of cash inflows and outflows for the 15 years of the analysis. The after-tax net cash flows are discounted on an annual basis using the WACC of capital. For example, this means that if we look at the after-tax net cash flow in year 8, it would be discounted back to year 0 using the following calculation: $= \frac{Net\ after\ tax\ cash\ flow_{t=8}}{(1.064)^8}$. This process is followed for each year of the investment and the summation of each year of the discounted after-tax net cash flow is the NPV, as reported in Table 13.

The 15-year NPV analysis found the gestation stall housing to have a positive NPV of $7.81M for a 6,400 sow unit. This suggests that a producer will make a larger return on the gestation stall housing barn investment than the discount rate (WACC = 6.4%) used for the analysis. Therefore, this investment should be made. The same conclusion does not hold for the 6,400 sow conventional group housing investment which resulted in a negative NPV of $1.52M. This means that the producer is receiving a lower return across the investments useful life than

the discount rate used. The difference between these two systems is important to note in interpreting the estimated NPVs. In particular, the conventional group housing system NPV had the same base revenue assumptions, however differences occurred with sow productivity and input costs. In particular, the conventional group housing system has a lower farrowing rate which results in fewer liveborn pigs per litter, decreased weaned pigs because of higher pre-weaning mortality, as well as increased sow mortality and decreased culling rates. The base scenario for group housing captures these differences, and that results in a NPV of -$1.52M. The $3.34 loss per weaned pig (Table 11) foreshadowed that the NPV would more than likely be negative, due to expenses being greater than the revenue generated for the conventional group housing with the assumptions used in this analysis.

Table 13. Baseline estimated NPV by housing system

Housing system	Stalls	Group Housing	Group Housing Increasing ft^2 per Sow‡	
Number of Sows	6,400	6,400	4,800	6,400
Cash Inflows, 15 years	142,889,408	128,960,224	97,141,128	129,521,504
Cash Outflows, 15 years	123,976,201	123,795,738	97,827,034	130,436,045
After-tax Net Cash Flows	14,874,807	528,326	-4,653,906	-6,673,261
Net Present Value (NPV)	**7,813,708**	**-1,524,067**	**-4,675,056**	**-6,701,461**

Note: ‡ Base scenario assumption is that conventional group housing and group housing with increased square feet per sow have the same operating expenses and sow productivity, all that differs is the facility investment cost.

When we apply the conventional group housing sow productivity and operating expense parameters to the group housing with increased square feet per sow barns, with their associated investment levels, we continue to observe negative NPVs. This means that the producer is receiving a lower return on this investment than the discount rate used for the analysis. Another interpretation is that the revenues generated over the 15 years of the asset's useful life do not cover the operating and fixed expenses of the system. Due to the negative NPVs, the investments should not be made. The other caveat to this base scenario is group housing with increased square feet per sow for a 4,800 sow unit results in approximately $31M less in cash inflows over the 15 years. If a farm chooses to have the same barn footprint as a conventional group housing system, they will have 25% less sows on the farm, and that is directly tied to less revenue and expenses. Through the data collection process, interviews with farmers and lenders indicated that most operations that choose to decrease their herd size by 25% would more than likely retain the same labor costs due to the labor required in group housing systems. That is not captured in this analysis, but it is an important point to mention, since the cash inflows and outflows are relatively close for the 4,800 sow group housing with increased square feet per sow barn without considering labor implications.

Increasing the barn footprint to house 6,400 sows in group housing with increased square feet per sow increases the overall investment to $28.79M. The NPV for the 6,400 sow group housing with increased square feet per sow system is more negative than the 4,800 sow

unit. This result occurs even with the increased revenue generated from additional sows due to the additional costs and non-cash depreciation for the larger investment level for the barn.

The results in Table 13 were generated as the base scenario. We do not have the data to identify differences in sow productivity and operating costs for group housing with increased square feet per sow, so this strategy allows us to compare the impacts of just the investment cost on the NPV and we observe large differences across those systems. The spreadsheet model is designed to readily make it possible to incorporate additional information as it becomes available. Buhr (2010) shows that minor changes in production parameters and costs can have substantial impacts on profitability. In the next section we complete a series of sensitivity analyses to identify which factors have the greatest impact on NPV across housing systems.

Objective 3: Conduct sensitivity analysis of NPV estimates to key inputs including feed and non-feed operating costs, interest rates, sow productivity, and up-front building costs.

A NPV analysis is dependent on the underlying parameters of the model. Sensitivity analysis of those parameters are often completed to identify the factors that have the greatest impact on the NPV. This can be thought of as a risk analysis where the distribution of possible outcomes is provided based on observed parameters. We estimate a series of sensitivity analysis for economic variables as well as productivity estimates. Only one factor is changed at a time to identify the impact of that variable on the NPV. The new NPV is compared to the base scenario NPV, as reported in Table 13. The difference between the two NPVs is reported to illustrate the impact of each variable.

Table 14 presents the impact of changing economic variables on the estimated NPV across all four housing systems. We report the base scenario value and associated NPV as well as the new value of the input of interest and the new estimated NPV. In the last column we report the difference between NPVs to provide a comparison in magnitude across housing systems as well as economic variables. The economic variables included in the sensitivity analysis include the facility investment cost, feed costs, non-feed operating costs, and interest rate. These changes were applied across all four housing systems for comparison.

The facility investment cost was increased by 15% for each housing system. USDA's National Agricultural Statistics Service publishes month indexes of prices paid by farmers. Recall, the building materials index increased 17% when comparing 2022 and the first five months of 2023 with 2021 (USDA-NASS, 2023). Another 15% increase seems at least plausible, so for the sensitivity analysis change, the per sow facility investment cost increases from $3,155 to $3,628 per sow for gestation stall housing for a total investment of $23,219,200. With this change, the NPV for gestation stall housing decreases by $2.05M. The conventional group housing investment increases from $3,622 to $4,165 per sow for a total investment cost of $26,656,000 and a NPV of -$4.67M. Increasing the per sow investment cost for group housing with increased square feet per sow from $4,499 to $5,174 per sow increases the total investment to $24,835,200 and $33,113,600 for the 4,800 and 6,400 sow units, respectively. Not surprisingly, this increased cost makes both group housing with increased square feet per sow facilities more negative in terms of NPV.

Table 14. Impact of economic variable sensitivity analysis on NPV across housing systems

Facility Investment Cost, $/sow	Base	+15%	Base NPV	NPV with Change	Difference
Gestation Stalls, 6,400 sows	3,155	3,628	7,813,708	5,761,546	-2,052,162
Group Housing, 6,400 sows	3,622	4,165	-1,524,067	-4,669,094	-3,145,027
Group, Increased ft^2, 4,800 sows	4,499	5,174	-4,675,056	-7,189,403	-1,673,912
Group, Increased ft^2, 6,400 sows	4,499	5,174	-6,701,461	-10,917,924	-4,216,643

Feed Costs, $/weaned pig	Base	+10%	Base NPV	NPV with Change	Difference
Gestation Stalls, 6,400 sows	12.84	14.13	7,813,708	6,377,034	-1,436,674
Group Housing, 6,400 sows	15.06	16.57	-1,524,067	-3,529,383	-2,005,316
Group, Increased ft^2, 4,800 sows	15.06	16.57	-4,675,056	-6,339,103	-1,664,024
Group, Increased ft^2, 6,400 sows	15.06	16.57	-6,701,461	-8,920,191	-2,218,730

Feed Costs, $/weaned pig	Base	-10%	Base NPV	NPV with Change	Difference
Gestation Stalls, 6,400 sows	12.84	11.56	7,813,708	9,250,382	+1,436,674
Group Housing, 6,400 sows	15.06	13.56	-1,524,067	276,976	+1,801,043
Group, Increased ft^2, 4,800 sows	15.06	13.56	-4,675,056	-3,071,843	+1,603,213
Group, Increased ft^2, 6,400 sows	15.06	13.56	-6,701,461	-4,563,844	+2,137,017

Non-Feed Operating Costs, $/weaned pig	Base	+10%	Base NPV	NPV with Change	Difference
Gestation Stalls, 6,400 sows	18.79	20.67	7,813,708	5,711,566	-2,102,142
Group Housing, 6,400 sows	21.50	23.65	-1,524,067	-4,429,496	-2,905,429
Group, Increased ft^2, 4,800 sows	21.50	23.65	-4,675,056	-7,063,953	-2,388,897
Group, Increased ft^2, 6,400 sows	21.50	23.65	-6,701,461	-9,886,657	-3,185,196

Interest Rates, %	Base	Change	Base NPV	NPV with Change	Difference
Gestation Stalls, 6,400 sows	7	10	7,813,708	5,248,003	-2,565,705
Group Housing, 6,400 sows	7	10	-1,524,067	-5,004,073	-3,480,006
Group, Increased ft^2, 4,800 sows	7	10	-4,675,056	-7,954,174	-3,279,118
Group, Increased ft^2, 6,400 sows	7	10	-6,701,461	-11,073,619	-4,372,158

The base scenario feed cost may be lower than the average producer due to the case farm having a feed mill as part of their operation. However, sow facilities of this size often have feed mills as part of their business structure or have volume discounts available because this volume of feed helps feed suppliers lower manufacturing, marketing, and delivery costs. Furthermore, the 2019-2023YTD average of feed costs does not fully account for the risk of future price increases in feed grains, supplements, concentrates, and complete feeds. We used an increase of 10% of the base scenario feed cost for the sensitivity analysis. The base scenario feed cost for gestation stall housing was $12.84 per weaned pig, which was increased to $14.13 per weaned pig. Again, this increased cost decreased the NPV over the gestation stall barn's

useful life. The conventional group housing and group housing with increased square feet per sow all had a base scenario feed cost of $15.06 per weaned pig, which was increased to $16.57 per weaned pig. This change has a smaller impact on the NPVs compared to the facility cost investment. The conventional group housing system NPV decreased by $2.01M. Both group housing facilities with increased square feet per sow experienced increased costs with NPVs decreasing by $1.66M and $2.22M for the 4,800 and 6,400 sow units, respectively.

Recognizing feed cost is a large share of total operating expenses, and can be rather volatile, feed cost was also decreased by 10% for the sensitivity analysis to identify potential positive impacts on the NPVs. The base scenario feed cost for gestation stall housing was $12.84 per weaned pig, which was decreased to $11.56 per weaned pig. This increased the NPV over the barn's useful life by $1.43M. The conventional group housing and group housing with increased square feet per sow all had a base scenario feed cost of $15.06 per weaned pig, which was decreased to $13.56 per weaned pig. This change positively impacted all three systems. In particular, the 10% decrease in feed cost resulted in a positive NPV of $276,976 for the conventional group housing system. This illustrates the importance of a sensitivity analysis and its ability to identify the inputs that can strongly impact the long-term financial viability of these large investments. Both group housing facilities with increased square feet per sow still experienced negative NPVs with the 10% decrease in the base feed cost.

Non-feed operating costs (per unit) may be lower on the large case farm providing data for our study because of their ability to negotiate volume discounts on some inputs, management ability, and other factors. Non-feed operating expenses include GDU costs, veterinary (including breeding fees), trucking, utilities, supplies, hired labor, manure management, and miscellaneous expenses. We apply a 10% non-feed operating cost increase across all four housing systems to show the sensitivity of the NPV to this increase. Again, across all housing systems NPVs decrease. Both group housing facilities with increased square feet per sow have a change of -$2.39M and -$3.19M for the 4,800 and 6,400 sow units, respectively. Moving to increased square feet per sow in group housing, requires a re-tooling of these economies of size and technology. Many of the personal interviews we conducted during the data collection process emphasized the additional labor needed to make these group housing systems work effectively. Labor is included in the non-feed cost estimate, and a number of the other operating expenses could increase in this new system. The sensitivity analysis shows that the results are very sensitive to increases in non-feed costs. One possible implication is that farms with cost advantages will be better positioned to transition to group housing with increased square feet per sow, but this also means that higher cost farms may exit the industry, and that market share will be captured by existing producers, not newcomers. Finally, this result demonstrates that the non-feed costs have a large impact on the financial success of a facility investment, regardless of the square footage per sow.

As interest rates continue to rise, we show the impact of increasing the interest rate from 7% to 10%. While we do not know the future of interest rates, the past 18 months has demonstrated that they have the potential to continue increasing (Federal Reserve Bank of Chicago, 2023). Increasing the interest rate to 10.0% increases the WACC from 6.4% to 7.3%. The interest rate also increases the interest expense payments over the 15 year loan, resulting in higher total loan payments. Not surprisingly, this change impacts all housing systems and decreases NPV estimates by $2.57M to $4.37M depending on the system. Keep in mind, the

total investment was held constant with this change. As an example, the annual loan payment for the 6,400 sow unit with increased square feet per sow in group housing increased from $2,529,106 to $3,028,483. A three percentage point increase in the interest rate increased total loan payments by $499,377, and this was for a system that wasn't able to break-even based on the cost of production.

In a second sensitivity analysis, we calculate the NPV for group housing with increased square feet per sow using a series of sow productivity changes (Table 15). We only apply this to group housing with increased square feet per sow. This provides a comparison to conventional group housing sow productivity and operating costs and how these changes could further impact the estimated NPV. Recall, the base scenario assumed the same sow productivity and operating expenses for conventional group housing and group housing with increased square feet per sow.

Table 15. Impact of sow performance and productivity sensitivity analysis on NPV for group housing with increased square feet per sow

Farrowing Rate, %	Base	Change	Base NPV	NPV with Change	Difference
Group, Increased ft^2, 4,800 sows	90	82	-4,675,056	-6,614,755	-1,939,699
Group, Increased ft^2, 6,400 sows	90	82	-6,701,461	-9,287,727	-2,586,266
Sow Mortality, %	Base	Change	Base NPV	NPV with Change	Difference
Group, Increased ft^2, 4,800 sows	11	14	-4,675,056	-5,026,550	-351,494
Group, Increased ft^2, 6,400 sows	11	14	-6,701,461	-7,170,120	-468,659
Pigs weaned pigs per sow per year	Base	-12% Change	Base NPV	NPV with Change	Difference
Group, Increased ft^2, 4,800 sows	25.53	22.47	-4,675,056	-7,247,905	-2,572,849
Group, Increased ft^2, 6,400 sows	25.53	22.47	-6,701,461	-10,131,927	-3,430,466

Farrowing rate has been cited as likely to decrease between 6 to 10 percentage points (Compeer Financial, 2021) in group housing with increased square feet per sow. We decrease the farrowing rate from 90% to 82%. This decreased farrowing rate results in a lower number of weaned pigs per sow per year from 25.53 per year to 23.21 for the 4,800 and 6,400 sow facilities. The decreased farrowing rate has a larger impact on the 6,400 sow unit due to the greater number of sows on the farm.

Increased sow mortality has also been identified as another likely potential outcome of group housing with increased square feet per sow. Lee, Sexton, and Sumner (2021) suggest sow mortality is likely to be higher by about 2 percentage points. Compeer Financial (2021) noted sow mortality likely increasing by 3 to 5 percentage points. Recognizing that many factors play into sow mortality, we increased sow mortality by 3 percentage points from the base scenario from 11% to 14%. The NPV estimates are $351,494 and $468,659 lower for the 4,800 and 6,400 sow units, respectively.

Lee, Sexton, and Sumner (2011) emphasize that many of the productivity measures are inter-connected—pigs weaned per sow are expected to decline by about 12%, partly due to sow mortality and partly because breeding becomes less efficient in a group setting. When we decreased weaned pigs per sow per year by 12%, to capture joint effects, there were 3.06 less weaned pigs per sow per year, which is a relatively large reduction. The NPV estimates are $2.57M and $3.43M worse for the 4,800 and 6,400 sow units, respectively. We chose to include this example to illustrate a lower productivity scenario. That is the reduced performance that could be accrued to the factors that contribute to the number of pigs weaned per litter and/or litters per sow per year. It is important to note that there will likely be some learning by doing and differences in productivity may narrow over time, however, productivity impacts are incurred every period making any differences notable over time.

Discussion

The results of this analysis demonstrate that a group housing system with increased square feet per sow does not cash flow using the base assumptions of conventional group housing operating costs and production performance. With the base scenario, the conventional group housing and 4,800 and 6,400 sow group housing with increased square feet per sow systems resulted in a negative NPV. These negative NPVs continued to worsen as we completed our sensitivity analyses by increasing selected costs as well as adjusting productivity parameters based on information collected from multiple sources. Again, this part of the analysis was to evaluate if the investment will generate enough revenue to cover all the expenses associated with the day-to-day operations as well as the cost of the building. Including the investment cost and the associated tax implications of that investment through depreciation and interest expense deductions illustrate these cost savings do not outweigh the associated cost increases within the context of the new system. Overall, these results demonstrate that the system does not cash flow when the annual estimates are discounted back to today's economic value to capture the longevity of this investment.

Each producer making this investment decision wants to ensure that they will not be worse off with this new investment. The question quickly becomes: what input parameters can be adjusted to improve the NPV? Traditionally, we can solve for the level of input changes needed to have an NPV=0, but that just means that the decision maker would be indifferent between this investment and another. In addition to this standard analysis, we want to discuss what would need to change to make the NPV of conventional group housing and group housing with increased square feet per sow equivalent to gestation stall housing ($7.81M).

If we approach this from a revenue perspective holding all expenses constant at the base scenario for group housing with increased square feet per sow, the premium needed per weaned pig to result in a break-even (NPV=0) for conventional group housing is $1.26 per weaned pig (Table 16). The premium needed for conventional group housing to have the same NPV as the gestation stall housing is $9.00 per weaned pig. Critically, this premium would be required over the entire 15 year investment. Extending this same process to 4,800 sow unit group housing with increased square feet, and a premium of $4.67 per weaned pig is needed for the NPV to equal zero. If we solve for the $7.81M NPV, the needed premium is $14.93 per weaned pig for 15 years. When we apply the same process to the 6,400 sow unit, the premiums

needed would be $5.07 and $12.79 per weaned pig to be no worse off compared to the NPV equal to zero and NPV equal to $7.81M (gestation stall housing), respectively.

The difference in these premium ranges illustrate a very important point regarding the size of the operation. While the base scenario per unit costs for the 4,800 and 6,400 sow group housing with increased square feet per sow are identical, the fixed expenses differ based on the total investment and the associated principal and interest payments of the facility. This affects their cost structure in different ways. The 4,800 sow unit generates less total revenue overall, but they still need to cover the cost of the investment, this results in a larger premium needed compared to the 6,400 sow unit to be no worse off than if they were operating a conventional group housing or gestation stall housing system. Decreasing the sow herd to meet space requirements with a similar building footprint causes ripple effects within this decision space. The operation has less pigs to cover these potentially increased costs, and if productivity parameters, such as weaned pigs per sow decrease, then those cost implications will only magnify this difference.

Table 16. Weaned pig prices needed for group housing systems to achieve an NPV = $7.81M and $0

Housing System	Baseline NPV ($)	$/weaned pig needed if NPV = $7.81M	$/weaned pig needed if NPV = $0
Group Housing, 6,400 sows	-1,524,067	56.25	48.51
Group, Increased ft^2, 4,800 sows	-4,675,056	62.18	51.92
Group, Increased ft^2, 6,400 sows	-6,701,461	60.04	52.32

*Premium calculation = $/weaned pig price needed if (NPV = $7.8M or $0) less $47.25.

There are multiple factors that affect the NPV over an investment's useful life. If we focus on the premiums needed based on the sow performance and productivity sensitivity analysis, we observe premiums ranging from $4.99 to $8.39 per weaned pig for NPVs equal to $0 and from $13.11 to $19.58 per weaned pigs when we solve for NPVs equal to the gestation stall housing NPV of $7.81M (Table 17). The largest premiums needed are when we assume that pigs weaned per sow decrease by 12% following Lee, Sexton, and Sumner (2021). Specifically, the weaned pig price needed for the 4,800 sow unit to be no worse off than a gestation stall housing is $66.83 per weaned pig, which results in a premium of $19.58 per weaned pig. Again, these premiums are needed over the entire 15 year period. When we apply the same process to the 6,400 sow group housing unit with increased square feet per sow, we observe premiums of $8.39 per weaned pig to achieve an NPV of $0 and $17.16 per weaned pig to result in a $7.81M NPV. Again, these premiums illustrate the impacts of economies of size between the 4,800 and 6,400 sow unit. Since the 4,800 sow unit has less sows and less weaned pigs, they need a higher premium to generate the same NPV as the larger sow unit. If they cannot secure a higher relative premium, the smaller sow unit will need to find additional cost savings to be no worse off decreasing their herd size to adhere to the increased square feet group housing specifications.

Table 17. Weaned pig price needed for NPV to equal $7.81M or $0 for the sow performance and productivity sensitivity analysis

Farrowing Rate, %	Base	Change	$/weaned pig needed if NPV = $7.81M	$/weaned pig needed if NPV=0
Group, Increased ft^2, 4,800 sows	90	82	65.59	54.31
Group, Increased ft^2, 6,400 sows	90	82	63.25	54.75
Sow Mortality, %	Base	Change	$/weaned pig needed if NPV = $7.81M	$/weaned pig needed if NPV=0
Group, Increased ft^2, 4,800 sows	11	14	62.50	52.24
Group, Increased ft^2, 6,400 sows	11	14	60.36	52.64
Pigs weaned pigs per sow per year	Base	-12% Change	$/weaned pig needed if NPV = $7.81M	$/weaned pig needed if NPV=0
Group, Increased ft^2, 4,800 sows	25.53	22.47	66.83	55.18
Group, Increased ft^2, 6,400 sows	25.53	22.47	64.41	55.64

*Premium calculation = $/weaned pig price needed if (NPV = $7.8M or $0) less $47.25.

A challenge exists in identifying the costs that can change to improve the estimated NPVs (Table 18). We know that the investment cost per sow for building new construction is high. Numerous conversations with producers and agricultural lenders indicate that increasing the barn size does not appear to result in decreased construction costs per sow. In our analysis we held the construction cost the same between the 4,800 and 6,400 sow unit to control for a consistent construction cost, regardless of sow unit size. Our results demonstrate that increasing this cost by 15% worsens the NPV resulting in weaned pig selling prices ranging from $58.60 to $64.24 to reach an NPV = $7.81M across the conventional group housing and increased square feet group housing systems. This decreases to a price range of $50.87 to $55.25 per weaned pig when solving for an NPV equal to zero. While it would be optimistic to assume that construction costs may decrease in the future, the assumption that they will continue to be at the base scenario level ($4,499 per sow) or potentially increase to the value used in the sensitivity analysis ($5,174 per sow), may be more than likely and with these changes the NPV still remains negative.

Economic indicators, such as interest rates, have a strong impact on the results. Interest rates impact the total loan payments, which has a ripple effect on cash outflows, income tax calculations, and the discount rate. Most of our analysis has been comparing what would need to change to have a positive NPV similar to gestation stall housing or a break-even NPV equal to zero. If a 10% interest rate was our long-term interest rate, which was a reality for many farmers in the 1990s and early 2000s, then we would only observe a positive NPV for the gestation stall housing system. Additionally, this 3 percentage point increase in the interest rate (7% to 10%) had the largest impact on the estimated NPVs across all housing systems in the sensitivity analysis. As interest rates continue to rise, this identifies one cost component outside

the control of the producer which may have a large financial impact on an investments ability to cash flow.

Table 18. Weaned pig price needed for NPV to equal $7.81M or $0 for the economic variable sensitivity analysis

Facility Investment Cost, $/sow	Base	+15%	$/weaned pig needed if NPV = $7.81M	$/weaned pig needed if NPV=0
Gestation Stalls, 6,400 sows	3,155	3,628	49.08	42.15
Group Housing, 6,400 sows	3,622	4,165	58.60	50.87
Group, Increased ft^2, 4,800 sows	4,499	5,174	64.24	54.13
Group, Increased ft^2, 6,400 sows	4,499	5,174	62.97	55.25

Feed Costs, $/weaned pig	Base	+10%	$/weaned pig needed if NPV = $7.81M	$/weaned pig needed if NPV=0
Gestation Stalls, 6,400 sows	12.84	14.13	48.54	41.60
Group Housing, 6,400 sows	15.06	16.57	57.75	50.01
Group, Increased ft^2, 4,800 sows	15.06	16.57	63.68	53.42
Group, Increased ft^2, 6,400 sows	15.06	16.57	61.55	53.83

Feed Costs, $/weaned pig	Base	-10%	$/weaned pig needed if NPV = $7.81M	$/weaned pig needed if NPV=0
Gestation Stalls, 6,400 sows	12.84	11.56	45.97	39.03
Group Housing, 6,400 sows	15.06	13.56	54.74	47.00
Group, Increased ft^2, 4,800 sows	15.06	13.56	60.67	50.41
Group, Increased ft^2, 6,400 sows	15.06	13.56	58.54	50.81

Non-Feed Operating Costs, $/weaned pig	Base	+10%	$/weaned pig needed if NPV = $7.81M	$/weaned pig needed if NPV=0
Gestation Stalls, 6,400 sows	18.79	20.67	49.13	42.19
Group Housing, 6,400 sows	21.50	23.65	58.40	50.65
Group, Increased ft^2, 4,800 sows	21.50	23.65	64.32	54.07
Group, Increased ft^2, 6,400 sows	21.50	23.65	62.19	54.47

Interest Rates, %	Base	Change	$/weaned pig needed if NPV = $7.81M	$/weaned pig needed if NPV=0
Gestation Stalls, 6,400 sows	7	10	49.68	42.93
Group Housing, 6,400 sows	7	10	59.23	51.22
Group, Increased ft^2, 4,800 sows	7	10	65.97	55.28
Group, Increased ft^2, 6,400 sows	7	10	63.71	55.69

*Premium calculation = $/weaned pig price needed if (NPV = $7.8M or $0) less $47.25.

Operating expenses were included in the sensitivity analysis as feed and non-feed cost adjustments. Increasing feed cost by 10% decreased NPV estimates by $1.44M to $2.22M across the four housing systems. Premiums needed for an NPV to equal zero range from $2.76 to $6.58 per weaned pig for conventional group housing and increased square feet group housing. When we decreased the feed cost by 10% we observed NPV estimates improving, with the conventional group housing system switching from a negative NPV to positive NPV. This can be observed in Table 18 with the break-even price of $47.00 per weaned pig for an NPV=0. This means that the 10% decrease in feed costs allows for a $0.25 per weaned pig profit for conventional group housing. The group housing systems with increased square feet still have a negative NPV with decreased feed costs with all break-even prices reported greater than $47.25 per weaned pig.

Changes to feed costs does not just necessarily impact this one cost category, there are possible secondary impacts. A feeding program has the potential to impact sow and pig health, which influences other costs within the system. Disentangling feed cost from these other factors is challenging for producers as well as in the context of this study. Our approach to addressing this was to also increase non-feed costs by the same amount, 10%. Non-feed operating expenses include all costs that are associated with the day-to-day operations of pig production, but the largest cost within that group is labor. Through the data collection process, the increased labor for group housing was voiced repeatedly. Labor contributes approximately 30% of all non-feed operating expenses. If more labor is needed or wages need to increase to retain good employees or attract new employees, these pessimistic estimates may be closer to some producer's reality.

Operations of the size level in our study are often some of the most efficient in the industry. They have achieved this efficiency due to cost savings and management potential. While the easy answer is always, decrease operating expenses, this analysis indicates that these costs may already be at a level that is the most efficient to-date. If that is the case, then the way to improve NPVs of the investment would be to achieve higher premiums to accommodate the probable increased costs and changes in sow productivity associated with the increasing the square footage per sow in group housing systems.

It is important to note that so far we have said nothing about the premiums currently being paid in the marketplace for sow housing practices. Price premiums provide some signal on what packers believe is the profit maximizing price for hogs with such attributes. Premiums are the result of demand as well as additional costs to produce pork with a particular claim. Consequently, to determine whether to target a market, producers need to understand both the added cost to produce for a particular market and the price elasticity of demand for the product.

Many hogs in the United States are marketed using a base price, which is then adjusted up or down given carcass characteristics. Signals being sent on desired weight and quality characteristics are different across packers and include premiums and discounts for lean percentage, sort loss, backfat, and/or loin depth. These price adjustments can change over time but are relatively stable. Additionally, packers often pay premiums if hogs possess extrinsic attributes valued by consumers. The premiums paid for non-carcass merit characteristics reflect market conditions and may be affected by shifts in supply and/or demand. It is important to recognize that just because a packer pays a premium for a hog that was produced with certain

practices, the entire carcass may not capture a premium in the marketplace. That is, the premium cannot be re-captured evenly across all the pork cuts harvested from the hog. Rather, sellers will have to recover the premium paid from those cuts for which there is demand of such attributes. Other cuts or grinds may simply be marketed at regular commodity price.

The premium categories in the USDA-AMS National Weekly Direct Swine Non-Carcass Merit Premium (LM_HG250) report include adjustments for volume, transportation, delivery time, breed, pork quality assurance, beta agonist free, and other. The other category is a catch-all for premiums that do not fit the other categories. Premiums are reported on a dollars per hundred pounds ($ per cwt) carcass weight basis. A range is provided for each category as is the weighted average.

Until recently, premiums for characteristics such as sow housing were not published. This may have been because there was not enough information to meet confidentiality guidelines.[9] Starting in August 2017, USDA began including all "other" premiums in one category. The other category is defined by USDA to include: "Animal Welfare, Antibiotic Free, Diet/Feed, Genetics, Meat Quality, Process Verified Program, Sow Housing, and Weight." As may be expected, the range in the other premium is quite large. The difference between the high end of the range and low end of the range was $14.75 per cwt in 2018, $19.08 per cwt in 2019, $26.53 per cwt in 2020, $29.90 per cwt in 2020, and $27.26 in 2022 (Figure 1). The weighted average was $3.72, $4.68, $5.72, $5.60, and $4.56 per cwt in 2018, 2019, 2020, 2021, and 2022, respectively. Beginning the week ending November 19, 2022 the high end of the "other" range decreased by about 60% and this has persisted throughout 2023. One explanation for this is a packer(s) quit offering a premium of this level. This premium would have likely been for a bundle of non-carcass merit characteristics. Looking back, this was foreshadowed by instances when the high end of the "other" range decreased to around $10-$13 for a week or two.

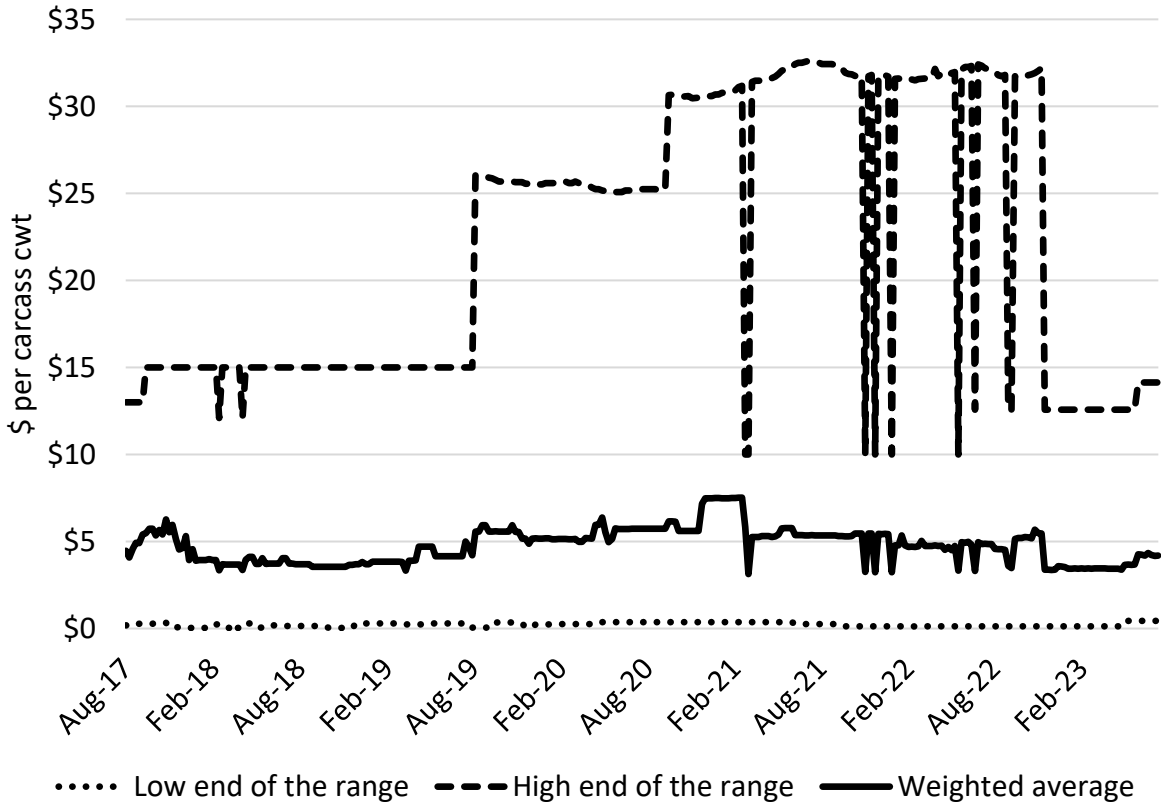
A few conditioning comments should be offered prior to any further interpretation of these data. The value of market information depends upon the level of aggregation in the published data. Combining all "other" non-carcass merit premiums together addresses confidentiality constraints and allows the data to be published. However, combining the premiums reduces the content of the market information that is discernable. For example, it is unknown how much of the "other" premium value is attributable to a "sow housing" premium and how much may be due to a possible bundle of additional other characteristics, i.e., animal welfare, antibiotic free, diet/feed, genetics, meat quality, process verified program, and/or weight. Furthermore, if premiums with divergent market values are combined, e.g., hypothetically the "sow housing" premium is increasing while premiums for "process verified programs" are decreasing, this could result in published market information that is difficult to interpret or of little value. The tradeoff is clear, aggregation might increase publishing ability, but at the cost of information content and value.

Providing additional published information or reports and/or providing market information in finer granularity would be an important avenue for USDA-AMS together with

[9] Protecting identity of reporting entities and maintaining confidentiality of individual transactions is required by the Livestock Mandatory Reporting Act of 1999. For more information visit https://www.ams.usda.gov/sites/default/files/media/ConfidentialityGuidelines.pdf

industry to assess. For example, could disaggregation of the "other" category in the LM_HG250 report to separately publish "sow housing" information be possible? This information may or may not be publishable because of the existing confidentiality guidelines. Assessing if publishing would be possible if volumes over multiple weeks, months, or even years were combined is an avenue for further research. A forum for asking these questions, and more, is the annual USDA Data Users meeting. The offering of new reports or new data has often originated from requests of pork market participants.

Figure 1. Non-Carcass Merit Premium: Other



Data source: USDA-AMS National Weekly Direct Swine Non-Carcass Merit Premium (LM_HG250) report.
Notes: Week ending August 5, 2017 through the week ending July 15, 2023. *Other category includes: Animal Welfare, Antibiotic Free, Diet/Feed, Genetics, Meat Quality, Process Verified Program, Sow Housing, and Weight.

As the name indicates the premium categories in the USDA-AMS National Weekly Direct Swine Non-Carcass Merit Premium (LM_HG250) are for market hogs. Knowing how these premiums translate to a per weaned pig basis would be prudent for cost benefit calculations. The USDA-AMS National Direct Feeder Pig Report does not publish any such premiums. As consumer demand varies, the impacts flow down through the marketing chain to producers through derived demand. Understanding shifts in derived demand within the supply chain at specific points in time is complex. For instance, even when consumers are willing to pay more for pork possessing certain characteristics, the retailer buying wholesale pork may not be. Likewise, the packer may not be willing to pay more for hogs. The primary reason is costs. Derived demand for wholesale pork by retailers reflects the prices they are willing, and able, to

pay for a given quantity of pork at the wholesale level. In a competitive market, the difference between the retail pork price and the wholesale pork price is the cost of getting wholesale pork to the retail meat case. Suppose those costs rise. Derived demand for wholesale pork by retailers declines, which equates to a lower wholesale price for the same quantity of pork supplied. Consumers aren't changing their retail demand; but wholesale demand is changing. Similarly, suppose packers' costs rise significantly. Further suppose that retail demand and wholesale demand hold steady. Packer demand will shift down, and prices for hogs, and pigs, will decline.

The Swine Contract Library (SCL) contains a listing of contracts offered by packers to swine producers for the purchase of swine (Federal Register, 2010). The SCL is intended to aid in the price discovery process and provide equal access to market information for all market participants. As of July 19, 2023 the various Swine Packer Marketing Contract Summary reports list specific "loose sow housing" premiums.[10] These values are $1.00 and $3.00. From these summary reports its unclear if these values are listed on a per cwt or per head basis.

The *Packer Marketing Contract Summary – National Other Provisions* report, contained within the SCL, lists "Business Practices - Animal Husbandry," several of which are specific to sow housing. These contracts are not without risks to producers. Premiums are often needed over the entire life of the investment as was shown in our NPV and sensitivity analysis. What happens if recent laws requiring producers to provide a minimum amount of square feet to breeding pigs in gestation are overturned? Or, what if the rules are changed, impacting the type of facility and housing practice used? Some existing contract terms that pertain to these questions include:[11]

- "Buyer may change the definition of loose sow housing unit if buyer determines, in its sole discretion, that an industry standard practice or definition emerges with respect to loose sow housing that differs from the definition of loose sow housing unit included herein. If buyer determines to change the definition of loose sow housing unit, buyer will provide seller at least one-year written notice of such change prior to such change becoming binding on seller. If seller cannot or will not make the changes required to meet the changed definition of loose sow housing unit, seller will inform buyer of such fact in writing immediately upon determination, and, in such event, this addendum (and this addendum only) will terminate."
- "Should the standards established by specified state livestock care board or other entity that would establish production standards, create a variance in square footage allowed for sow/hogs in current production, both parties agree to reestablish the minimum number of hogs required to be purchased/sold each year under specified paragraph of this agreement for the duration of this agreement."

As a producer and owner of production facilities, there are several questions that need to be answered before entering into a contract with a packer. Additionally, with the added investment in a facility and ongoing costs to meet contract terms and specifications, it is reasonable to expect a return to not only cover the additional costs but also achieve a reasonable return on investment.

[10] https://www.ams.usda.gov/rules-regulations/packers-and-stockyards-act/regulated-entities/swine-contract-library.
[11] https://www.ams.usda.gov/sites/default/files/media/SCLCSROP.pdf.

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