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Economic Impact of Transitioning from Gestation Stalls to Group Pen Housing in the U.S. Pork Industry

by
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EXECUTIVE SUMMARY

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NEED FOR STUDY

Modern swine production systems rely heavily on confinement production systems for cost effective and humane production of pork products. However, there are increasing calls to reduce or eliminate the use of individual sow gestation stalls for housing breeding sows and gilts. The European Union is phasing out stall use by 2013. Voters in Florida and Arizona have approved ballot initiatives to ban their use in the coming years, and in 2007 the Oregon Senate passed a bill banning gestation crates. Restrictions on gestation crates have also entered the U.S. Farm Bill discussions.

Imposition of regulatory requirements on production methods will result in significant costs to producers and ultimately consumers who pay a higher price for pork products. This study examines the economic costs of transitioning the U.S. swine production sector from a breeding sector based on gestation stall facilities to one based on group housed pen facilities.

DO PENS IMPROVE WELFARE AND MAINTAIN PRODUCTIVITY?

Prior research on sow productivity and welfare suggests that the type of system does not necessarily determine sow welfare. Stalls allow for individual sow management and remove the potential for sow aggression and injury, but sows are incapable of full movement. Pens allow for greater mobility, but also allow sow aggression that can result in injury and also extreme variation in body condition between aggressive and submissive sows.

It is also not clear that productivity differs between gestation stalls and pens. Prior research has found no significant productivity differences. A survey was conducted asking producers using pen housing on a commercial scale to address productivity impacts. This survey also found no consistent difference in productivity. However, respondents indicated several key issues would affect group housing productivity: (1) producers must learn to manage group dynamics of sows; (2) some stall use must be available for up to 32 days after breeding for proper implantation and also for isolation of sows when they 'fall-out' of pens; (3) feeding for management of body condition variation is critical; (4) space allocation per sow relative to pen size is critical; and (5) the potential for catastrophic productivity losses are greater with pens. So, although there does not appear to be significant differences on average in production, there are significant risks posed by transitioning the industry from stalls to pens in a short time frame.

BASE ASSUMPTIONS AND SCENARIOS FOR ECONOMIC ANALYSIS

The economic analysis is based on the economic impact of transitioning from gestation stall housing to group pen housing under a regulatory mandate. The capital costs of transition are evaluated in addition to the potential impacts of differences in productivity.

To determine the economic impacts on the pork industry of a transition to pen housing, two alternative pen systems were simulated: a trickle feed system with small pens of six or fewer sows and an electronic sow feeding (ESF) system with large pens of 50-60 sows. The trickle feed system is simpler to operate and implement as a retrofit, but may require additional barn square footage. The ESF is technically more sophisticated with the potential for greater management and maintenance issues, but allows for sows to be housed on the same square footage as existing stall systems. Both systems were scaled to a commercial level of 2400 and 1200 sow units.

The capital replacement cost is modeled so that the additional cost of retrofitting or replacing an existing barn prior to the end of its depreciable life (about 25 years) results in increased capital costs, but no improvement in revenue if productivity is unchanged. This is modeled as an infinite horizon net present value problem. To aggregate impacts to an industry level requires estimation of the number of barns to be replaced or retrofitted and the average age of the barns to determine their useful life lost. Based on USDA data it is estimated that 1,725 barns with 1200 sows would need to be transitioned and 1,370 barns with 2400 sows would need to be transitioned. No information is available on barn age, so the ages are assumed to be uniformly distributed over 25 years.

Three scenarios are analyzed: (1) the productivity costs are unchanged between stall and pen based gestation and the only cost is the capital cost of retrofitting stall facilities or building new pen systems; (2) in addition to the capital costs, it is assumed that productivity decreases for two years during the transition, this is the most likely scenario; and (3) the productivity decreases are persistent for the life of the facilities, this is the worst case scenario.

BARN LEVEL ECONOMIC IMPACTS

The following table shows the most likely impacts of a transition to pen housing assuming a uniform distribution of the age of existing facilities at the time a regulation requiring transition is introduced. Industry losses will range between $1.87 billion and $3.24 billion.

Most Likely Aggregate Industry Economic Costs of Transitioning to Group Pen Housing

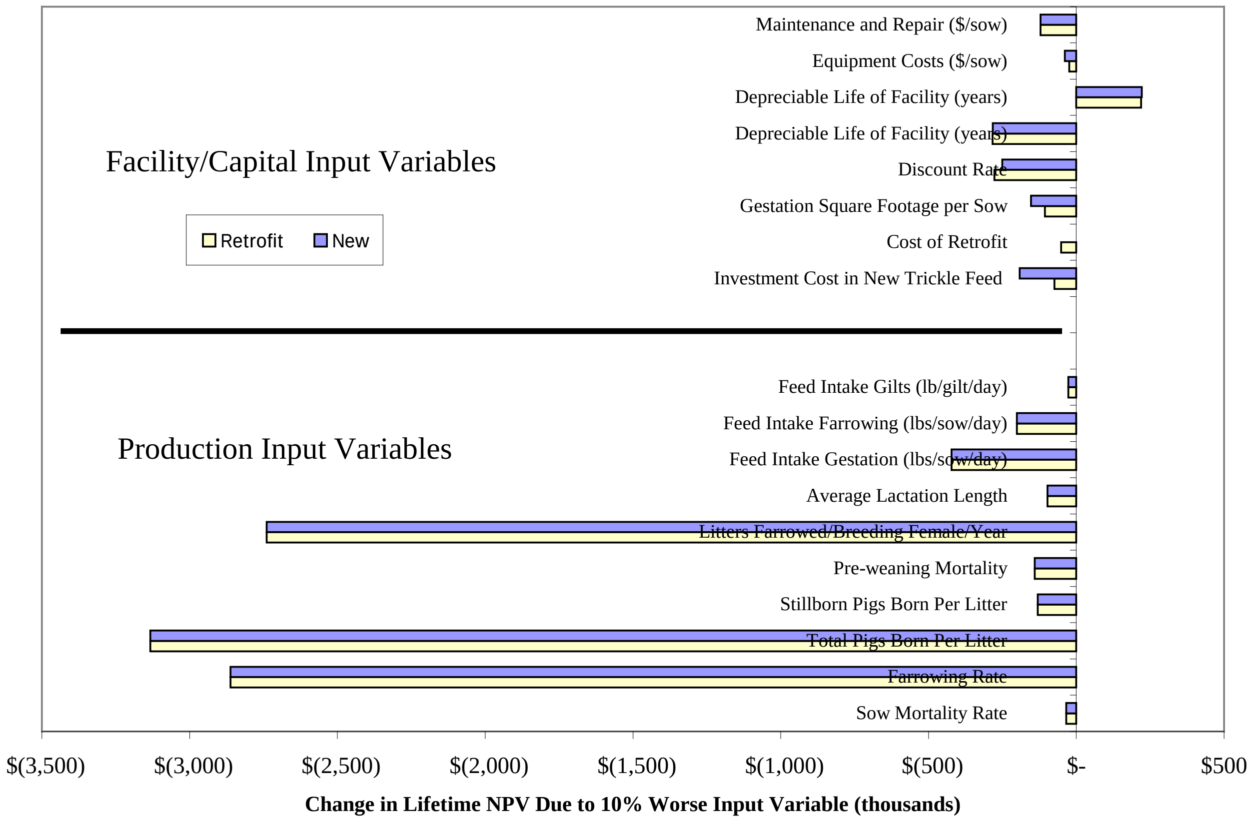
	Capital Cost Plus 2 Year Productivity Loss	
Scenario	**Total Industry Cost**	Percent Decrease in Industry NPV
Total Average Cost to Retrofit Barns to Trickle Feed	**$ 1,867,892,023.74**	74%
Total Average Cost to Build New Trickle Feed	**$ 3,240,730,303.66**	129%
Total Average Cost to Build New ESF Feed	**$ 3,237,111,517.39**	97%

Note: ESF percent decrease is lower because the cost basis of the stall barn comparison was also different.

Several factors affect these losses. The shorter the time period for transition the greater will be the economic losses. If productivity losses are permanent, which may be reasonable if pen facilities are more difficult to manage, the losses will increase. The best case is to allow barns to transition at the end of their useful life, and with no loss in productivity from group housing sows. Also, because facility ages likely do vary by region and firm, even policies which allow transitioning at the end of facility life will create structural competitive differences among firms and regions. Those with older average age facilities will benefit more relative to those with newer facilities.

SENSITIVTY OF ECONOMIC IMPACTS TO ASSUMED VARIABLE LEVELS

The levels of key input variables such as sow productivity measures, depreciable life of the barns, and the transition period can impact the economic estimates of the costs of a transition to group housing. A sensitivity analysis was completed, varying the level of key input variables used in the simulation. The following graph shows the relative impact of a 10% change in these input variables on the net present value producers will receive after the transition. Results show that as expected productivity variables such as farrowing rate have the greatest impact on profitability. Therefore, it is imperative to determine expected productivity impacts. Capital costs are not as crucial because the one time transition is eventually amortized from the production system.



MARKET LEVEL ADJSUTMENT TO THE TRANSITION

As the cost of pork increases due to the transition to group housing, hog production will be expected to decrease and hog and pork prices will increase. A market supply and demand model including trade is used to analyze the market level price/quantity adjustments. The following table shows the impacts on consumer and producer surplus which is a net measure of the increases in prices and reductions in quantities from market response to higher costs of production.

The key implication is that pork producers lose $1.5 billion dollars; less than half the approximately $3.2 billion they lose if market adjustments are not accounted for. As typical of cost increases in a commodity market, consumers bear most of the cost increases resulting in an estimated $5 billion loss to consumers.

Beef and chicken producers gain because consumers switch consumption to these meats and their prices rise as well. A similar substitution effect occurs for imported pork products which increase to replace the more expensive domestic pork products. Therefore, regulations to restrict sow housing will place the U.S. pork sector at a competitive disadvantage to other domestic meat sectors and to international pork production if they don’t adopt similar standards.

Most Likely Impacts on Market Level Producer and Consumer Costs

Variable		ESF Productivity Impacts 2 year Transition
Change in Producer Surplus (Net Impact)		
Pork Producer Surplus	Mill $	**-$1,491.30**
Beef Producer Surplus	Mill $	**$1,193.20**
Chicken Producer Surplus	Mill $	**$469.23**
Change in Consumer Surplus		
Pork Consumer Surplus	Mill $	**-$2,714.12**
Beef Consumer Surplus	Mill $	**-$1,698.46**
Chicken Consumer Surplus	Mill $	**-$576.34**
Total Consumer Surplus	Mill $	**-$4,988.92**

An argument is typically made that increased animal welfare is demanded by consumers and they will compensate producers by paying higher prices. However, as clearly shown the market alone will not compensate producers. To fully compensate pork producers would require an additional 25 percent increase in consumer willingness to pay for U.S. pork products from sows raised in pens. The problem is that only a small subset of consumers is actually willing to pay a large difference for animal friendly practices. Consumers not willing to pay for these practices are essentially taxed by a regulation that mandates costly production practices such as the transition to pen housing.

CONCLUSIONS

Any regulation that mandates transition to pen based housing from existing stall housing prior to the end of the useful life of existing facilities will result in increased costs to the pork industry. Ultimately these costs will be borne by consumers. An alternative approach is to allow phase-in as barns reach the end of their useful life, but only if it can be determined that there are no reductions in productivity or sow welfare due to pen housing which will require further research and preferably commercial scale research trials. Perhaps the best alternative is to develop labeling and certification programs which allow producers and consumers who share concerns regarding gestation stalls to more effectively participate in market oriented transactions. This would avoid the aggregate cost impacts of a large scale mandatory transition, and allow consumers to target their spending to preferred animal rearing methods and products.

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Need for Study

Modern swine production systems rely heavily on confinement production systems for cost effective and humane production of pork products. However, there are increasing calls to reduce or eliminate the use of individual sow gestation stalls for housing breeding sows and gilts. The European Union is phasing out stall use by 2013. Voters in Florida and Arizona have approved ballot initiatives to ban their use in the coming years, and in 2007 the Oregon Senate passed a bill banning gestation crates. Restrictions on gestation crates have also entered the U.S. Farm Bill discussions.

In addition to regulatory pressures, agri-food companies are considering moving towards policies restricting the use of gestation crates in the interest of consumer perception regarding the welfare of sows. On January 25, 2007, Smithfield Foods announced that it would convert all of its company owned sow facilities to group housed pens within 10 years (Smithfieldfoods.com). In an interview in the Washington Post (January 26, 2007) Smithfield cited increased concerns of its customers "such as McDonald's and several supermarket chains" as a motivation for changes.

Very few studies examine the economic differences between gestation stall and gestation pen housing. Those that do exist have focused solely on the between system productivity at the farm level. No studies reviewed for this analysis considered the issue of the economic costs of transitioning the U.S. pork industry as would be necessary under policies similar to those passed by states. This project is intended to examine barn level economic effects of productivity, management and welfare, and the subsequent issue of how to transition the existing gestation to farrowing facilities to group pens. This includes issues of capital investment as well as market level price and quantity effects. The goal is to properly characterize the issue for discussion and to provide estimates of how alternative scenarios might affect the pork industry and consumers.

Previous Research on Sow Gestation Housing

Production Performance Impacts of Transitioning to Group Housing

A significant amount of previous research exists on the production performance of sows maintained in individual stalls compared to group housing. Three excellent reviews of the literature include Barnett et al. (2001), McGlone et al (2004) and Rhodes et al. (2005). All focus on summarizing published research on production and behavior comparisons between stall housing and group housing systems.

McGlone et al. summarized 35 articles and attempted to control for confounding factors in comparing research conducted under different circumstances. McGlone et al. focused on eight key factors of production, behavioral and physiological performance. Production performance variables included: farrowing rate, piglets born alive per litter, total pigs born per litter, and piglet birth weight. Behavior factors included: Oral-Nasal-Facial (ONF) behaviors and stereotyped bar biting. The only physiological measure was the level of cortisol in sows. None of the selected measures were found to be statistically different between individual stall systems and group housing systems. The study concludes that:

> *"Within the restrictions of the methodology adopted for 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. Each system for housing gestating sows has opportunities for improvements in sow welfare based on additional research and development."*

Rhodes et al. took a similar approach but the methodology was a subjective review rather than a statistical test of differences between individual stalls and group pens. Their conclusions also showed no major differences in sow welfare dependent on housing type. However, differences were often observed that offset one another. For example, the report concluded that gestation stalls may adversely affect behavior by restricting movement, but that group housing adversely impacted sows by allowing aggressiveness resulting in biting. They also found no evidence of differences in production performance.

Rhodes et al. also considered the cost comparisons of moving from individual sow stall systems to group housed systems. All studies reviewed were based on European systems, but found that a switch to group housing from stall housing resulted in between a 0.6% and 2% increase in costs per finished pig. Only one study reviewed included capital costs and the time necessary to transition the industry from stalls to group housed systems.

Barnett et al. focus on similar aspects, but include a broader array of studies, examining differences in tethered, stall, conventional indoor group housing and outdoor group housing. As with Rhodes et al. and McGlone et al., Barnett finds that housing systems per se do not seem to influence welfare. However, underlying factors such as method of feeding, design of facility, stockmanship, diet, genetics, mating, can either improve or harm welfare in any type of facility.

Although these literature reviews must be interpreted within their context, a general consensus of research is that there is no clear difference in productivity that can be attributed to stalls or group housing systems. In each case the actual implementation of the housing system is crucial to performance and welfare of the sows. For example, if sows are group housed, they form a social hierarchy that is manifested in feeding behavior, so that if all of them are fed together, dominant sows will typically be over-fed and submissive sows will be underfed (Brooks, 2003). A way Brooks identified to overcome this is electronic sow feeders (ESFs) which allow sows to enter an enclosed feeder by themselves and not be bothered by other sows (Figure 1).

Other issues include the necessity of proper management based on housing design, the size of groups housed in a pen, how groups are managed (dynamic v. static), how breeding and periods of early implantation of the embryo are managed, floor type, pen size, ventilation, and inclusion of bedding or straw (Thibault, 2004). As with production performance these facility and design characteristics affect the welfare of pigs, and both individual stall and group housed pen facilities can be designed to obtain similar welfare outcomes. In other words proper design of stalls or pens can result in equivalent animal performance and welfare outcomes although the design features to achieve that objective will differ. Therefore, it's not clear that simply switching to group housing will inherently improve or reduce sow performance or welfare.

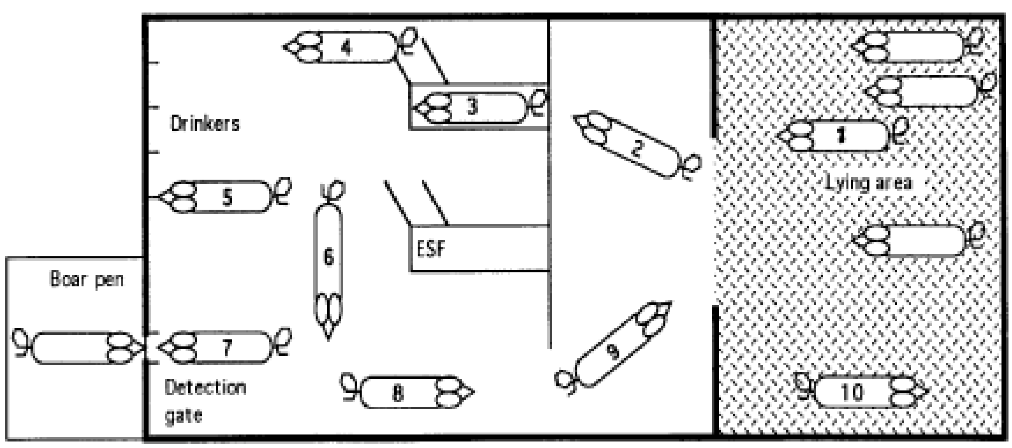

Figure 1. Sample Configuration with Electronic Sow Feeders (ESF). Source: Brooks.

Previous Economic Comparisons of Sow Housing

Few studies have examined the comparative economics of gestation stalls to group pens and only one was found to have addressed the issue in the U.S (Lammers et al.). A study by den Ouden et al. (1997) considers consumer demand and production cost impacts of an array of animal welfare production changes, including a switch from stalls to group housing in the Dutch pork industry. In an analysis of seven respondent rankings of their concerns of animal welfare, the highest importance rate was given to housing non-lactating sows, suggesting at least in this very small sample that respondents reflect concerns of gestation housing. Experts in animal welfare concerns were more than doubly concerned with housing in stalls than were consumer related respondents.

Den Ouden et al. also provide an expected cost coefficient of changing from gestation stall housing to group housing was 2.78 florins with a base total cost per finished animal produced of 357 florins (a 0.78% increase in costs per finished hog). Although not specifically defined, the cost differences are clearly related to a barn level comparison – that is the cost of owning and operating a gestation stall facility versus the cost of owning and operating a group housing facility, including productivity differences and capital costs.

A second study by the Von Borrell et al. (1997) done as a report of the European Union Scientific Veterinary Committee more specifically examined the economic calculations comparing individual stall housing to group housing for dry sows (section 6.3.3). The basic sow farm included 165 sows housed in partial slatted crates for farrowing and gestation. The alternative group house system was based on the same total number of sows, with static sow groups of 25 sows per pen (small pen) and with an ESF system. The analysis assumes no differences between the two systems in performance factors including: weaned piglets per sow, growth rate of fattening pigs, feed conversion, mortality rate and health costs. They state: "*This is because literature and expert opinion most often differ on the precise relationship between welfare improving measures/systems and the level of these performance parameters.*"

Therefore, economic differences originate from other costs. In the basic analysis, results show a reduction in investment costs per sold piglet from 56.71 to 56.37 eurocents and a labor *income* increase of 8% with the change. They attribute the lower cost to the removal of expensive crates, but also acknowledge that results are highly sensitive to labor and management assumptions and are reversed if the group housing system includes any form of crate for feeding.

It also depends on space allocated to group housed sows, and an increase in space from 2 square meters per sow in the base case to 2.5 meters results in a cost per sold piglet of 56.55 eurocents and an increase to 3 meters per sow increases the cost beyond the base stall assumption (56.71 ecus) to 56.74 ecus.

A recent study of the cost impacts of gestation housing (Lammers et al, 2007) in the U.S. compared conventional individual stall facilities to group housed sows in hoop barns. The analysis was a budgeting exercise based on surveyed construction costs of stall facilities but actual costs of an experimental hoop facility at Iowa State University. Their results include some improved production performance in live pigs born per litter in hoop facilities, but primarily relied on differences in facility investment costs. Overall variable costs of production were $25.15 per wean pig produced in stalls and $25.55 per weaned pig produced in the group – hoop facility. However, fixed costs (dominated by investment costs) were $9.13 per wean pig in the stall facility and $7.59 for the hoop facility. Total cost per weaned pig produced in the conventional stall facility is estimated as $34.28 compared to a total cost for the hoop facility of $33.09 per pig weaned. The shortcoming of the study is that it's highly unlikely hoop facilities will replace existing commercial facilities, and it does not address the fact that existing stall facilities will need to be retrofitted or replaced to accommodate pen housing.

Survey of Group Housing Operations in the U.S.

Gestation stall housing is well defined in the U.S. because a prototypical system has been installed as the industry modernized in the past 25 years as shown in Figure 2. Rows of individual gestation crates are separated by aisles. Crates typically measure 7 feet by 2 feet, and walkways average 2.5 feet. There may be more or fewer rows depending on the dimensions of the overall barn. There will be pens for boars, and perhaps pens for health treatments. Feeding systems include individual lines that drop into feeder pans in the crate (typically stainless steel). The housing of sows in individual crates improves the ability to manage each sow individually and removes group dynamics of feeding and social behavior that affects sows.

In contrast, ask the question of what group housing is and you may come up with a dozen different answers. No prototypical pen based housing has emerged, largely because of its limited application on the commercial level which has limited the evolution of systems to fit commercial scale.

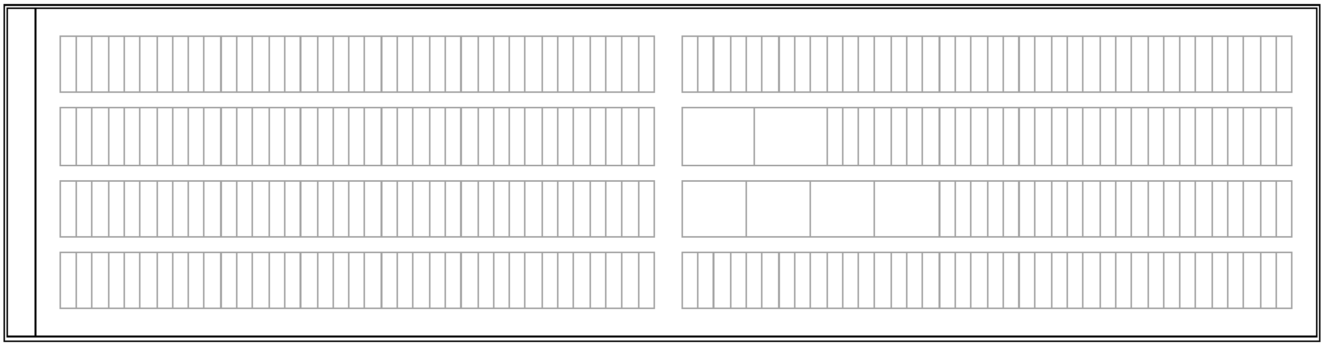

Figure 2. Prototypical Gestation Stall Barn Diagram.

To better understand some of the issues faced by early adopters of pen based sow housing a telephone survey was conducted. Respondents included an academic researcher (1), commercial swine producers (5), and building and equipment manufacturers (2) with extensive knowledge of both stall and group housed systems. Others were contacted but had not responded at the time of the completion of this report. The survey is included in Appendix A along with producer responses to questions. It addresses issues of production performance, labor and management issues and the costs of transitioning or investing in gestation stall facilities versus group housed facilities. The survey was first e-mailed to respondents so they could gather information and consider their responses. The survey was actually completed via a telephone interview with respondents. This allowed for open ended responses to all questions.

Survey Results

Systems surveyed included large pen systems (greater than 50 sows in a pen) and small pen systems (6 or fewer sows in a pen). Systems included one producer with a relatively new electronic sow feeding system (ESF) and a building company which has experience in building ESF equipped barns with large pens. Other producers used drop or trickle feed systems and one builder with experience in building trickle feeding systems in a small pen environment was interviewed. One immediate challenge is that the pens were non-standard, making it difficult to generalize information. For example, one system had been originally built in the 1980’s and had been added onto since as the operation grew, so there was no specific definable structure. Another system was having success converting finishing barns to group housing of sows, so again non-standard. Yet a third had ceased production due to early design difficulties. Of course this results in relatively little solid information on the cost impacts at the farm level of commercial scale pen housing. It also illustrates why the industry is very concerned: the conversion is a leap into uncertainty with very few production and financial guideposts.

Of the questions regarding key performance parameters, only farrowing rates were consistently lower for pen systems averaging 2.8 percent lower than stall systems. This was frequently attributed to issues with getting sows to settle in a pen environment. Nearly every respondent indicated that it was necessary to allow a minimum of 28 days post breeding in individual stalls to improve embryo implantation and a best case of 32 days. This was reflected already in builders' barn designs that included individual stalls for breeding and for fall-outs from pens (see Appendix B). Hence, any requirement to eliminate stalls completely, even for breeding and settling sows, could dramatically impact productivity.

Stillborns tended to be higher by 17% for pen systems, but at least one producer reported significantly lower stillborns. Stillborns is a small number in general, so that it does not have much impact on overall productivity.

Other production performance parameters (total pigs born, pigs weaned, and birthweight) were reported by the majority of respondents as not being remarkably different in stalls versus pens, consistent with previous research. In cases with differences, there were two conflicting reports of increasing or decreasing performance. Hence, as with previous research, the major finding is that it is possible to have similar performance across the two systems.

In addition to production performance, questions were asked with regard to the sows' observed welfare. This included questions about observed lameness, lesions, biting, death loss, and stereotypic behavior. All respondents indicated significantly more lameness in sows housed in group pens. Based on culling rates or treatment, respondents on average estimated a 15% increase in lameness. Flooring and particularly slat configurations were frequently cited as contributing to lameness problems. Slats designed for group housing with narrower spaces (preferred 1" in group housing) are not as likely to catch sow's feet and reduce lameness. Also, it is important that slats are in good condition with consistent spacing between slats. It's also frequently stated that it is critical to maintain dry flooring in circumstances with partial slats. However, none indicated this significantly affected any performance parameters.

All respondents indicated that lesions and biting were a fact of pen based housing. In photos offered by one respondent, all sows clearly exhibited shoulder bites and scratches, although few were severe. All respondents also indicated that biting was worse within one to two weeks of farrowing when they observed marked increases in vulva biting. Hence, some had indicated they were placing sows into farrowing crates a bit earlier to reduce the incidence of this behavior.

The central issue of sow health, welfare and productivity indicated by respondents was sow condition related to feeding and nutrition. This is also the intersection between operation management and facility design. Kirk Brincks of Hog Slat, Inc. provided an excellent categorization of group housing systems available on a commercial basis (Table 1)[1]. These included, ESF systems, free stall/loafing, trickle feeding, drop feeding and a combination mechanical sorting and trickle feeding systems. Simply reading through Table 1, illustrates that each system has its advantages and disadvantages, and that there is no clear solution emerging.

However, it also identifies key issues that will affect the industry transition. This includes how easily existing barns can be retrofitted to accommodate a pen system? What are the changes in the facility footprint (square footage) necessary to accommodate the same number of sows to align with the farrowing and finishing ends of the production system? How is labor and management affected with each system? To this last question, from interviews it became clear that labor and management was changed in group housing compared to stall housing. However, the change represented a tradeoff and only one respondent specifically indicated a need for additional labor of about 16 percent or one additional worker in a typical crew of six. Tradeoffs included such issues as pig movement being reduced, easier access to pens- walkthrough was much faster because more sow contact is made with fewer aisles, pregnancy checking and treatment didn't create significant problems and so labor remained essentially unchanged. None indicated significant worker training requirements, and no additional concerns regarding worker health or injury rates. One respondent indicated that workers enjoyed working in the group house barn more than stall barns because it was better ventilated (less density), had less dust and was much quieter than the stall systems.

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[1] Early schematics of several systems are provided in Appendix B. These are meant only to provide a visualization of differences in systems, and not necessarily as representative of turnkey building plans.

Although all reported management was approximately the same, several respondents had only a small share of their total production in pen based facilities. While they indicated that the pen based barn hadn't significantly increased management they recognized they had spent a greater amount of time, and perhaps included one of their top sow managers in the new pen facility. Still, none reported excessive management requirements. Whether this is true on large scale implementation is questionable, but even farms that had multiple operations with pens reported no additional management requirements compared to stalls.

Table 1. Comparison of Major Alternative Feeding Systems

System Type	Key Characteristics	Advantages	Disadvantages
ESF	• Computerized Feeding • Large Group Pens. • Per sow spacing 18 sq ft. • Fully slatted • RFID electronic tags • Database control	• Individual Feed Intake • Condition Control • Protection at feeding • Recordkeeping • Same barn footprint • Low Capital Cost vs. stalls	• High repair/maintain • Tag loss/reliability • High vulva biting waiting in line. • Any failure = feed out • Pig training
Mechanical Sort	• Large Group Pen • Food/water courts • Mechanical sort to feed or pen • Electronic Tags • Midway ESF/Other systems	• Individual animal monitoring. • Less equipment cost relative to ESF. • Similar barn footprint • Low cost relative to stall. • Record keeping • Dynamic groups	• High repair/maintenance • Higher cost: feed equip and sort equip both. • Difficult retrofit • Tag loss/reliability • Less ability to monitor individual feed intake.
Free Stall/Loafing	• Combine groups and feeding stalls • Roam large pen • Feed in stalls • Body length or partial stalls • Can have self locking free access stalls.	• Protection while feeding. • Protection in general. • Good retrofit. • Same feed equipment.	• Space may be 35 ft^2/hd • Very expensive – stall plus pen. • May increase footprint by 50% • No individual feeding or conditioning of sows
Trickle Feed	• Deliver feed over long period (15-30 minutes) • Small pens 5-6 sows • Min 20 sq. ft /sow	• Feed 'fixation' reduces fighting. • Good retrofit to existing barns. • Cost similar to stalls • No training • No complex equipment • Existing feed systems	• Only small groups • 15-20% space reduction in barn. • No individual feeding to body condition. • Must group for size and aggression.
Drop/Manual Feed	• Hand feed small group pen • Feed on solid floor • Mechanical feed drops • Small pens 4-5 sows • 16 – 20 square feet per sow.	• Least cost system • Easy Retrofit • Husbandry • No complex equipment	• Aggressive feeding behavior. • Body condition variability – especially heavy. • Labor may be higher.

Source: Interviews and material provided by Kirk Brincks, Hog Slat, Inc.

Respondents are likely representative of early adopters, with high technical skills and a tradition of implementing and researching new technologies. This concern was expressed by respondents indicating that pen systems are subject to greater risk of production failures and that would be directly correlated with the quality of management. Hence, while this very small sample had adapted, there was some concern that wider spread adoption with high management intensity may lead to greater productivity losses. As an example, one respondent had implemented a new ESF facility in late 2005. In the first ten months of operation, he reported a 10 percent reduction in pigs weaned per mated sow, a 20 percent increase in cull rate, and a 40 percent increase in sow mortality. Through rigorous management, the next ten months of operation yielded results comparable to their stall based housing, and the comment that the barn is now one of their better performers. There were some indications that genetic adjustments would be necessary and are underway. One respondent, who recently constructed a large pen ESF barn, said they were in the process of selecting for less aggressive sows. Others had also made this comment, although none provided a cost of this transition.

No respondents had good cost estimates of facility design, so building contractors were contacted and their information is included in the economic assessment. Several commercial operations are in the process of specifying new pen gestation facilities, so in the next two to three years it is expected that many of the issues addressed here will be clarified by on farm results. It will be very important to re-examine these results in the near future.

Overall, the survey suggested that productivity, management and welfare of sows housed in pens compared to stalls were similar. However, several critical issues must be addressed for successful pen housing: (1) stalls must be available for breeding and settling otherwise productivity will suffer, (2) maintaining body condition is critical to success and more difficult in pens versus stalls and is the critical link between barn design, management and productivity, (3) husbandry becomes more important because the group dynamic must be managed, (4) facility design including flooring is critical to success; poor design will reduce productivity and has greater potential to reduce sow welfare.

Baseline Technical and Economic Assumptions

Transition costs depend on several factors: (1) the feasibility and costs of retrofitting existing stall facilities into group housed facilities compared to complete construction of new facilities, (2) the remaining useful life of the existing facilities and the useful life of renovating these facilities compared to constructing new facilities (3) the amount of time available to make the transition if there is a time limitation (for example the EU and Smithfield both offered target transition periods of 10 years) (4) any subsequent differences in operation and production operating net profits after the refurbishment, (5) space allocation requirements for pen versus stall facilities which will determine if new buildings must be constructed to accommodate existing production levels and (6) the learning curve of management and labor in achieving comparable production results in a new system.

To address these factors, a model of the gestation and farrowing segment of the hog production process is created. Two prototypical systems are developed; one based on 1200 total sows and one based on 2400 sows per gestation/farrowing complex. Baseline production assumptions are shown in Table 2 for the 2400 sow system. The 1200 sow system is proportionally equivalent and is not shown. The sizes are selected to maintain the current structure and animal numbers of the industry relative to wean-finish capacity. The productivity parameters can be adjusted to account for scenarios of stall and pen facilities performing differently. All barns are assumed to be deep pitted systems with tunnel ventilation.

Transition to pen based systems will require either retrofitting existing gestation facilities or constructing new facilities. As shown in Table 1, there are at least five broad alternatives for configuration. Two key facility designs were used to narrow down the possibilities. One is a trickle feed small pen system and the other is a large pen electronic sow feeding (ESF) system. Both are constructed based on actual designs of commercial building contracting firms. These are not intended to show actual construction or retrofitting costs, but are only used to parameterize simulations. Trickle feed and ESF systems were chosen because they provide good contrast of potential impacts. The trickle system is technically easier to operate and likely has lower ongoing maintenance and management costs. Its original cost is higher because it is expected that greater square footage per sow is required (20 square feet minimum) and this requires larger barns. In contrast the ESF system can maintain the same square footage as existing stall barns (about 18 square feet per sow including walk-ways), and with fewer pens has a lower investment cost. However, it is technically more advanced and has greater potential for maintenance and management costs.

Table 2. Production Coefficient Assumptions 2400 Sow Facility

Number Sows	2,400	head
Farrowing Capacity	378	head
Gestation Capacity	2,022	head
Average Annual Cull Rate: Breeding Females	40%	
Average Annual Mortality Rate: Breeding Females	7%	
Farrowing Rate	83%	
Total Pigs Born Per Litter	10.5	pigs
Stillborn Pigs/Litter	0.6	pigs
Pigs Born Alive/Litter	9.9	pigs
Pre-Weaning Mortality	0.8	pigs
Weaned Pigs Per Litter	9.1	pigs
Pig Birth Weight	1.5	lbs
Litters Farrowed / Breeding Female / Year	2.3	litters
Weaned Pigs Sold Per Sow Per Year	21.0	pigs
Avg Lactation Length	20.0	Days
Avg Gestation Length	114.0	Days
Average Days in Gestation Barn/Litter	132.3	Days
Total Days is Gestation	307.5	Days
Days in Crate Prior to Farrowing (Pre-load)	5.0	Days
Total Days in Crate	57.5	Days
Percent of Time in Gestation	84%	
Avg Live Weight (lbs) / Standard Weaned Pig	12.0	lbs
Weaned Pigs Transferred Per Year	41,981	pigs

(Source: Lammers et al., ISU, 2007 and KSU MF-2153, and PigChamp Summaries)

The basic building costs of a stall gestation/farrowing facility is shown in Table 3. In this case the building contractor provided the cost figure for the complete turn-key facility and the proportion of costs allocated to farrowing and gestation, respectively. Building and equipment costs are broken out because they have different lifespans. In the case of retrofitting facilities, the equipment may be replaced prior to the building, and logically if that occurs at about 12.5 years when the initial equipment is fully depreciated, there may be no additional costs from eliminating equipment with a useful remaining life. A 1200 sow facility is proportional in costs and so is not shown.

Table 3. Estimated Facility Costs of 2400 Sow Stall Gestation and Farrowing Facility

Total Cost, Concrete, Equipment, Building, Office	$ 1,425	/sow
Total Farrowing Cost Share	45%	
Farrowing Building Cost Share	69%	[a]
Farrowing Equipment Cost Share	31%	[a]
Farrowing Building Estimated Total Cost	$ 1,054,240.98	
Farrowing Equipment Estimated Total Cost	$ 484,759.02	
Gestation Building Cost Share	73%	[a]
Gestation Equipment Cost Share	27%	[a]
Gestation Building Estimated Total Cost	$ 1,370,475.83	
Gestation Equipment Estimated Total Cost	$ 510,524.17	
Site Preparation, engineering, excavation, landscaping etc.	$ 80,000.00	[a]
Depreciable Life of Buildings	25	years
Depreciable Life of Equipment	12.5	years

[a] Source: KSU MF-2153

Table 4 shows the cost assumptions for a new 2400 sow trickle feeding system with small pens (5-6 sows per pen). The cost of the farrowing barn component does not change. However, the contractor estimates that approximately twenty percent more gestation building square footage is required to accommodate the same sows as in a stall system. This represents approximately a ten percent increase in the overall gestation and farrowing project cost. The increase in square footage in the gestation barn and the elimination of more expensive stalls and feed pans in the pen facility cause the proportion of costs allocated to the building portion of the gestation barn to increase while the equipment costs decrease.

The contractor also provided estimates of retrofitting existing stall barns into small pen trickle feed systems. This would be potentially beneficial if an existing stall based system was reasonably new and the producer was forced to convert to pens. To convert a barn to small pen trickle feeding requires the removal of stalls, but existing flooring can be maintained. Pre-poured concrete walls and panels are incorporated and can be configured so that existing feed lines can be used if not already fully depreciated. The conversion of stalls to pens is estimated to cost $150/sow. However, as with the new trickle feeding barn, more square footage is required so that a new barn must be built if the same size sow herd is to be accommodated. The new trickle feed barn to house approximately 289 sows will cost about $1,000/square foot. Based on an assumption of 20 square feet per sow, the total estimated conversion cost of a 2400 sow site using gestation stalls to a trickle feed small pen site would be approximately $731,429.

Table 4. Estimated Facility Costs of 2400 Sow Trickle Feed Small Pen Gestation and Farrowing Facility

Total Cost, Concrete, Equipment, Building, Office	$	1,568	/sow
Total Farrowing Cost Share		na	
Farrowing Building Cost Share		na	
Farrowing Equipment Cost Share		na	
Farrowing Building Estimated Total Cost	$	1,054,240.98	
Farrowing Equipment Estimated Total Cost	$	484,759.02	
Gestation Building Cost Share		80%	
Gestation Equipment Cost Share		20%	
Gestation Building Estimated Total Cost	$	1,778,400.00	
Gestation Equipment Estimated Total Cost	$	444,600.00	
Site Preparation, engineering, excavation, landscaping etc.	$	80,000.00	[a]
Depreciable Life of Buildings		25	years
Depreciable Life of Equipment		12.5	years

[a] Source: KSU MF-2153

The ESF facility is only constructed as a new replacement facility. The contractor interviewed for this building indicated that existing barns can be retrofitted, but it was highly dependent on the existing configuration of flooring and feeding systems. Further, ESF is cheaper than other systems to build; therefore, it will usually make sense to simply build a newly designed ESF barn than to retrofit older barns. If the transition is necessary before existing barns are fully depreciated this will represent a significant loss of asset value. Table 5 shows the cost assumptions for a new 2400 sow ESF feeding system with large pens (66 sows per pen, 18 sq ft per sow). The comparable facility advantage of ESF is that it can conceptually fit the same number of sows on the same footprint of existing stall facilities if sows are housed at about 18 square feet per sow. As with the trickle feed system, there is assumed to be no change in the farrowing costs. The ESF is less expensive because the there is less penning material, there is actually less total feeding equipment, less labor is required on the barns and there is less concrete.

Table 5. Estimated Facility Costs of 2400 Sow ESF Feed Large Pen Gestation and Farrowing Facility

Total Cost, Concrete, Equipment, Building, Office	$	1,277	/sow
Total Farrowing Cost Share		na	
Farrowing Building Cost Share		na	
Farrowing Equipment Cost Share		na	
Farrowing Building Estimated Total Cost	$	1,054,240.98	
Farrowing Equipment Estimated Total Cost	$	484,759.02	
Gestation Building Cost Share		80%	
Gestation Equipment Cost Share		20%	
Gestation Building Estimated Total Cost	$	1,283,987.20	
Gestation Equipment Estimated Total Cost	$	320,996.80	
Site Preparation, engineering, excavation, landscaping etc.	$	80,000.00	[a]
Depreciable Life of Buildings		25	years
Depreciable Life of Equipment		12.5	years

[a] Source: KSU MF-2153

There are several issues left unaddressed in building cost issues. For example, each design incorporates as many as 290 individual stalls for breeding and settling sows before moving them to pens and for holding sows that are fall-outs from pens. Clearly, the complete elimination of stalls will adversely affect productivity, particularly in the breeding stage. It's also not clear that group housing is the preferred system. One building contractor had examined all commentary on group housing and said there was no apparent requirement for sows to be group housed, but rather that they are able to turn around. Hence, an alternative system of individual pens which would eliminate group dynamics but allow individualize animal treatment may be an alternative design that captures the best of pen and stall systems. The trade-off would be an approximate doubling of square footage and approximately doubling of gestation facility costs making it the most expensive alternative. Another issue is how to maintain productivity as barns are converted. The contractor retrofitting barns suggested depopulation would require approximately 4-6 months, or a rolling conversion could be done as sows entered farrowing requiring perhaps 12 months, although neither had been attempted.

As a final step, partial budgets are created for each of the barns using the technical parameters and investment costs. Table 6 shows the partial budget for a 2400 sow breeding, gestation, farrowing operation (BGFW) with stalls. With no assumed productivity differences, the partial budgets for trickle feed pens and ESF feed pens are identical except for differences in capital costs. The budgets for 1200 sow units are also identical on a per weaned pig basis.

Tables 2-6 provide the basic gestation stall parameters for all subsequent simulation models. All scenarios are made to a baseline, so all results are relative to these base parameters. Therefore, while their precise magnitudes may affect the magnitude of impacts the relative changes will be consistent regardless of the magnitude of changes. The 1200 sow numbers are available on request, but as described above the changes are proportional except in cases where a value is multiplied by percentage terms in which case there are the typical scaling issues.

Assumptions for Aggregate Industry Analysis

To estimate the industry level impacts estimates of the number of barns that must be retrofitted or replaced and the average age of the barns are needed. If barns are newer when replaced, the costs of replacement will be greater because the barn will not yet have paid back the initial investment before incurring new capital costs that do not result in increased returns, but simply add on to the initial investment costs.

Unfortunately, there is no national database that provides the complete building inventory used for swine production in the U.S. Therefore, it was necessary to estimate these from related published data. USDA estimates of the number of hogs and pigs in the U.S. as of December 1, 2006 (Quarterly Hogs and Pigs Report, December 27, 2006, USDA/NASS) as well as USDA estimates of the number of locations that held at least one pig in inventory during 2004 (Farms, Land in Farms, and Livestock Operations: 2006 Summary, February 2007, USDA/NASS) were used as the basis of the estimates.

Table 7 shows the breakdown of facilities by size category and the assumption on average barn size that leads to an estimate of the total number of gestation barns. According to these reports, there were approximately 65,540 locations (operations) having at least one pig in inventory for some portion of 2006. As of December 1, 2006, the latest estimate available at the time of this report, there were approximately 62,149,000 hogs kept for all purposes in the U.S. inventory and 6,088,000 hogs kept for breeding purposes.

Table 6. Costs of Production for Weaned Pigs Stall Facility

Variable Costs						
Feed	$	8.97	/weaned Pig	$ 188.39	/sow	[a]
Labor	$	6.94	/weaned Pig	$ 145.73	/sow	[a]
Breeding/Genetic Charge	$	5.13	/weaned Pig	$ 107.72	/sow	[a]
Bedding	$	-		$ -	/sow	[a]
Utilities Fuel and Oil	$	1.79	/weaned Pig	$ 37.59	/sow	[a]
Sow Death Loss Charge	$	0.47		$ 9.84	/sow	[a]
Transportation and Marketing Costs	$	1.75	/weaned Pig	$ 36.75	/sow	[a]
Veterinary, Drugs, Supplies	$	1.10	/weaned Pig	$ 23.10	/sow	[a]
Professional Fees	$	0.48	/weaned Pig	$ 10.08	/sow	[a]
Interest on Operating Costs (.5 * others)	$	0.40	/weaned Pig	$ 8.47	/sow	[b]
Total Variable Costs	**$**	**27.03**		**$ 567.68**	**/sow**	

Depreciation Calculations Per Weaned Pig				
Useful Life Barns		25	years	
Useful Life Equipment		12.5	years	
Salvage Value Barns		10%		
Salvage Value Equipment		0		
Depreciation Per year				
Farrowing Building Depr.	$	37,952.68	/year	
Farrowing Equipment Depr.	$	38,780.72	/year	
Farrowing Building Salvage Value	$	105,424.10		
Farrowing Equipment Salvage Value	$	-		
Gestation Building Depr	$	49,337.13	/year	
Gestation Equipment Depr.	$	40,841.93	/year	
Gestation Building Salvage Value	$	137,047.58		
Gestation Equipment Salvage Value	$	-		
Depreciation per Weaned Pig				
Farrowing Building Depr.	$	0.75	/weaned pig	
Farrowing Equipment Depr.	$	0.77	/weaned pig	
Gestation Building Depr	$	0.98	/weaned pig	
Gestation Equipment Depr.	$	0.81	/weaned pig	
Total Depreciation	**$**	**3.31**	**/weaned pig**	
Fixed Costs				
Depreciation costs on Buildings and equipment	$	3.31	/weaned pig	[b]
Interest on Buildings and Equipment	$	3.05	/weaned pig	[b]
Insurance and Taxes on Buildings and Equipment	$	0.89	/weaned pig	[b]
Building and Equipment Repairs	$	1.70	/weaned pig	[b]
Total Fixed Costs	**$**	**8.95**	**/weaned pig**	
Total Cost Per Weaned Pig Sold	**$**	**35.98**	**/weaned pig**	
Full Valued Wean Pig Price	**$**	**40.00**	**/weaned pig**	
Gross Profits	**$**	**4.02**	**/weaned pig**	

[a] Based on estimates of Lemmers et al., 2007

[b] Calculated as in KSU, MF-2153

Table 7. Estimation of Size and Number of Gestation Barns in the U.S. Swine Industry, December 2006

Total U.S. Hog Inventory	62,149,000	head
U.S. Breeding Herd Inventory	6,088,000	head
Number of Operations by Inventory Size		
Less than 2000 Head Inventory	57,792	operations
Between 2000 and 50000 Head Inventory	7,633	operations
More Than 50000 Head Inventory	115	operations
Breeding Herd Inventory By Operation Size		
Less than 2000 Head Inventory	730,560.00	head
Between 2000 and 50000 Head Inventory	2,069,920.00	head = 34% share
More Than 50000 Head Inventory	3,287,520.00	head = 54% share
Assumed Barn Size by Operation Size		
Less than 2000 Head Inventory	12.64	head
Between 2000 and 50000 Head Inventory	1,200	head
More Than 50000 Head Inventory	2,400	head
Assumed Number of Gestation Facilities		
Less than 2000 Head Inventory	57,792	barns
Between 2000 and 50000 Head Inventory	1,725	barns
More Than 50000 Head Inventory	1,370	barns

There is a large variety of barn configurations and size differences among farms and therefore a distribution of barn types within each producer size category. For example, in the small category USDA further refines the size allocation to show that in 2006, 39,395 farms accounted for only 1 percent of U.S. inventories and had between 1 and 99 head on a farm. It is assumed that for the small category (< 2000 head) that the breeding herd is evenly distributed across all farms. This leads to only an average of about 13 sows per operation. For further context the smallest likely sow herd in this category would be 4 to 10 sows. In contrast, the largest end of this category would be farms with inventories of 1,000 to 1,999 hogs and comprise 5 percent of the U.S. inventory. The large scale group could consist of as few as 87 sows (farrowing 23 pigs per sow per year) or as many as 200 sows per year (weaning 10 pigs per sow per year). At the larger end of this spectrum producers may use gestation stalls. So within this category there are many potential configurations. However, the core assumption is that this segment of the industry relies less on gestation stalls than the larger segments and hence it is assumed that this 12% of inventory does not require a switch from stalls to pens. This is likely an underestimation of the use of gestation stalls in this category.

The medium size range distribution is less skewed with an even distribution of number of pigs between farms of sizes 2,000 – 4,999 head and farms of sizes 20,000 – 49,999 head. Sow inventories could again range from 200 to 2,200 sows for these operations. On the low end it's likely that many operations do not have gestation stalls, but beyond 600 sows, it is possible that gestation stalls exist in the operation. Assuming the medium size category is large enough to employ a standard 1200 sow multi-site unit, dividing the total inventory by 1200 sow increments yields 1,725 barns which would need to be converted within this category. In this case, it's expected that the number of barns to be converted may be slightly overestimated.

The large size category likely contains the least error, as these are most likely standardized production systems relying on 1200 to 2400 sow barns, but with some including 3,600 to 5,000 head facilities. The large category is broken into 2400 sow units and results in approximately 1,370 gestation barns needing to be converted. However, there are also as likely to be multiple 1,200 sow units comprising the smaller end herds, so it's not clear if this represents an under or overestimation of barns to be retrofitted. The estimation of barn numbers is ad hoc at best; however, if improved information becomes available they can easily be incorporated as parameters into the simulation model.

Scenarios and Analysis of the Direct Costs of Transitioning to Group Pen Housing

Two categories of scenarios are constructed. The first category assumes that all production performance is unchanged between stall and group pen gestation facilities. This scenario assumes that all increased costs are capital costs related to the transition from stall barns to group pen housing. The second category includes both the impacts of potential reductions in production performance as well as the capital cost impacts from the first category of scenarios. These two broad categories are then broken down to include differences in feeding systems (trickle feed small pens and ESF feed large pens), size of facilities (1200 sow and 2400 sow), and in the case of trickle feed pens the alternative of retrofitting existing facilities compared to building new pen facilities to replace the stall facilities.

Capital Cost Scenarios: Analysis Background

The baseline assumptions of parameters are shown in Tables 2-6. The scenario assumes that farms are required to either retrofit or rebuild facilities to accommodate group pens. The scenario is set up as a capital budgeting simulation. Barns are assumed to be fully depreciated (or have a useful life) at 25 years. If replacement occurs when barns are fully depreciated the capital costs would simply be the difference in costs between investing in a new group pen facility and a replication of the existing stall facility. So, a base scenario is that all stall barns are only replaced when they have reached the end of their useful life (25 years) and this is compared to replacing the facilities with stalls instead of pens. It would be possible under this scenario to make a voluntary economic decision to replace stalls with pens if pen gestation has the same or better performance impacts and lower capital costs.

The second scenario is to consider what happens if the conversion to pens occurs prior to the end of the useful life of existing facilities which would likely occur only in response to regulatory intervention. This significantly complicates the industry level assessment of capital costs of conversion. First, all existing stall barns were not built at the same time. So, for example, if a requirement existed to have barns converted within 10 years of the current time (as in Smithfield's proposal), barns which are older than 15 years currently could all be replaced at the end of their useful life which would occur within the 10 year conversion time. Barns newer than 15 years would all convert prior to the end of their useful life and would have remaining value prior to the conversion which is lost. Importantly, revenues are expected to remain unchanged because the conversion results in an equal producing facility so there is no additional return for making this added investment.

There is no known estimate of the distribution of the age of gestation barns in the U.S. An obvious subjective argument can be made that different regions have expanded at different times. For example, the period from 1996 through 1997 was one of the largest expansionary phases in the U.S. hog sector. Therefore, one would expect that a larger proportion of barns have been constructed within the past 15 years. Similarly, North Carolina was an early adopter of modern facilities and has had a moratorium on construction, so that it is likely that region's stock of facilities is older on average than the rest of the industry. However, rather than build complex assumptions, the essence of the analysis is captured by simply assuming that barns are uniformly distributed by age, so that 1/25 of the industry's barns were constructed over each of the past 25 years. The spreadsheet model is designed to readily make it possible to incorporate other assumed distributions if they become available.

Method of Capital Analysis: Infinite Horizon Net Present Value

Given that this is a time dependent capital budgeting problem the expected impact of each scenario is modeled as an infinite horizon net present value problem which discounts all changes back to a present value. This is also extremely useful for assessing the market level economic effects to be analyzed later. A single period net present value (NPV) analysis is applied to evaluate either a one time project or to compare the NPV of two projects with the same project life. However, if projects have different life cycles, then the proper method of analysis is to assume that each project can be reinvested in at the end of its life in perpetuity (Copeland and Weston, pp. 48-50). Given the fact that existing barns have different remaining lives, it is necessary to employ the infinite horizon NPV for analysis.

A typical net present value calculation is defined as:

$$NPV = \sum_{i=1}^{N} \frac{NCF_t}{(1+k)^t} - I_0$$

Where, NCF is the net cash flow in period t, k is the opportunity cost of capital to be used as a discount rate for the investment and I_0 is the initial investment required to begin the project, in this case the construction of a gestation and farrowing barn. However, if projects have different lengths, as will be the case in this circumstance if a regulation is put into place specifying a time frame for conversion and with existing barns of different lifespans, then the infinite horizon NPV is appropriate and it is defined as:

$$NPV(N,\infty) = NPV(N)\left[\frac{(1+k)^N}{(1+k)^N - 1}\right]$$

Where NPV(N) is the net present value as calculated for the single period project where N is the length of the project, and other terms are defined as before. This analysis is applied to determine the discounted impact on the pork industry of a transition from stalls to group pen housing.

Capital Cost Scenarios and Results

The net present value method relies on cash flows to evaluate the costs of alternative projects. Using baseline parameters from Tables 2-6, the estimated total cash flows for a 2400 sow stall gestation barn including activities of breeding, gestation and farrowing through weaning (BGFW) is compared to retrofitting or building a new 2400 sow trickle feed system with small pens as shown in Table 8.

Table 8. Cash Flow For Trickle Feeding Sow Housing Scenarios, 2400 Sows

Key Impact Variables:	Gestation Stall Facility	Retrofit to Trickle Feed Small Pens	New Trickle Barn
Total Variable Costs	**$ 1,362,241.90**	**$ 1,362,241.90**	**$ 1,362,241.90**
Beginning Farrowing Building Investment	$ 1,054,240.98	$ 1,054,240.98	$ 1,054,240.98
Beginning Farrowing Equipment Investment	$ 484,759.02	$ 484,759.02	$ 484,759.02
Beginning Gestation Building Investment	$ 1,370,475.83	$ -	$ 1,778,400.00
Beginning Gestation Equipment Investment	$ 510,524.17	$ 731,428.57	$ 444,600.00
Beginning Total Investment Costs	**$ 3,420,000.00**	**$ 731,428.57**	**$ 3,762,000.00**
Interest on Gestation Barns and Equipment	$ 84,645.00	$ 32,914.29	$ 100,035.00
Insurance on Gestation Barns and Equipment	$ 24,706.41	$ 24,706.41	$ 24,706.41
Maintenance and Repair - Gestation Barns	$ 47,025.00	$ 47,025.00	$ 47,025.00
Interest on Farrowing Barns and Equipment	$ 69,255.00	$ 69,255.00	$ 69,255.00
Insurance on Farrowing Barns and Equipment	$ 20,214.34	$ 20,214.34	$ 20,214.34
Maintenance and Repair - Farrowing Barns	$ 38,475.00	$ 38,475.00	$ 38,475.00
Other Cost Impacts	$ -	$ -	$ -
Other Cost Impacts	$ -	$ -	$ -
Other Cost Impacts	$ -	$ -	$ -
Other Cost Impacts	$ -	$ -	$ -
Total Costs of Production - BGFW	**$ 1,646,562.65**	**$ 1,679,476.94**	**$ 1,661,952.65**
Revenue from Full Value Weaned Pigs	**$ 2,015,904.00**	**$ 2,015,904.00**	**$ 2,015,904.00**
Net Cash Flow	**$ 369,341.35**	**$ 336,427.06**	**$ 353,951.35**

In the simulation, the initial investment is made in a 2400 sow prototypical stall gestation system, including farrowing facilities. This investment is $3,420,000 and is expected to generate an annual cash flow of $369,341.35 for the 25 year life of the facility. The infinite NPV of this investment assuming a cost of capital discount rate of 7 percent is calculated as $1,083,848, which means the facility generates positive returns and represents a reasonable investment alternative.

Retrofitting existing stall barns to include small pens with trickle feeding results in an additional investment of $731,429 that includes additional square footage to allow sows approximately 20 square feet per sow. There are no productivity differences assumed so variable costs are unchanged between scenarios. Similarly, if any reinvestment in farrowing buildings or equipment is required the investment cost remains the same as under stall systems. The only cost difference is that the new investment in pens results in increased interest costs on capital, therefore, the net cash flow is lower after retrofitting. The net cash flow for building a new trickle feeding barn is lower because the investment costs are higher for gestation primarily due to the increased square footage required to house sows.

Table 9 shows similar cash flows for a new 2400 sow ESF facility. In this case there is no consideration of retrofitting to an ESF since it is too dependent on the existing barn structure. The interpretation and analysis is the same as for the new trickle feeding barn.

Table 9. Cash Flow For ESF Feeding Sow Housing Scenarios, 2400 Sows

Key Impact Variables:	**Gestation Stall Facility**	**New ESF Barn**
Total Variable Costs	**$ 1,362,428.80**	**$ 1,362,428.80**
Beginning Farrowing Building Investment	$ 1,054,240.98	$ 1,054,240.98
Beginning Farrowing Equipment Investment	$ 484,759.02	$ 484,759.02
Beginning Gestation Building Investment	$ 1,261,414.80	$ 1,283,987.20
Beginning Gestation Equipment Investment	$ 469,897.20	$ 320,996.80
Beginning Total Investment Costs	**$ 3,270,312.00**	**$ 3,143,984.00**
Interest on Gestation Barns and Equipment	$ 80,940.22	$ 72,224.28
Insurance on Gestation Barns and Equipment	$ 23,600.84	$ 23,600.84
Maintenance and Repair - Gestation Barns	$ 44,966.79	$ 44,966.79
Interest on Farrowing Barns and Equipment	$ 66,223.82	$ 66,223.82
Insurance on Farrowing Barns and Equipment	$ 19,309.78	$ 19,309.78
Maintenance and Repair - Farrowing Barns	$ 36,791.01	$ 36,791.01
Other Cost Impacts	$ -	$ -
Other Cost Impacts	$ -	$ -
Other Cost Impacts	$ -	$ -
Other Cost Impacts	$ -	$ -
Total Costs of Production - BGFW	**$ 1,634,261.25**	**$ 1,625,545.31**
Revenue from Full Value Weaned Pigs	**$ 2,015,904.00**	**$ 2,015,904.00**
Net Cash Flow	**$ 381,642.75**	**$ 390,358.69**

Two simulations are conducted so that 25 representative barns (one for each year of age) are either retrofitted or built new to replace gestation stalls. A barn that is 25 years old is simply replaced with a new trickle feed system. A barn that is 24 years old could be retrofitted in the 24th year so it only loses one year of productive life from the initial stall investment. Then in the 25th year a new investment in a complete new system is made. This assumption is made because the barn itself is worn out at year 25 and the retrofit does not include the barn structure.

Clearly, the appropriate method is to optimize the decision to retrofit relative to building a new barn dependent on the age of the facility. However, for this analysis the assumption is simply that a regulation or policy is imposed and the decision to retrofit or build new is based on which yields the highest infinite horizon NPV based on age of the facility. This same logical progression occurs for each age of barn from one to twenty-five years. Figure 3 shows the trade-off between retrofitting and building a new barn in terms of the age of the facility. The appropriate action to take for any age of barn is determined by the highest net present value. Results show that for any barn that is 21 years or older, the decision that yields the highest NPV is to build a new trickle feed pen barn rather than retrofitting the existing barn. For any barns less than 21 years old, the best strategy would be to retrofit the barn and then in the 25th year of the useful life of the original barn, replace the complete system with a new trickle feed gestation barn and farrowing house.

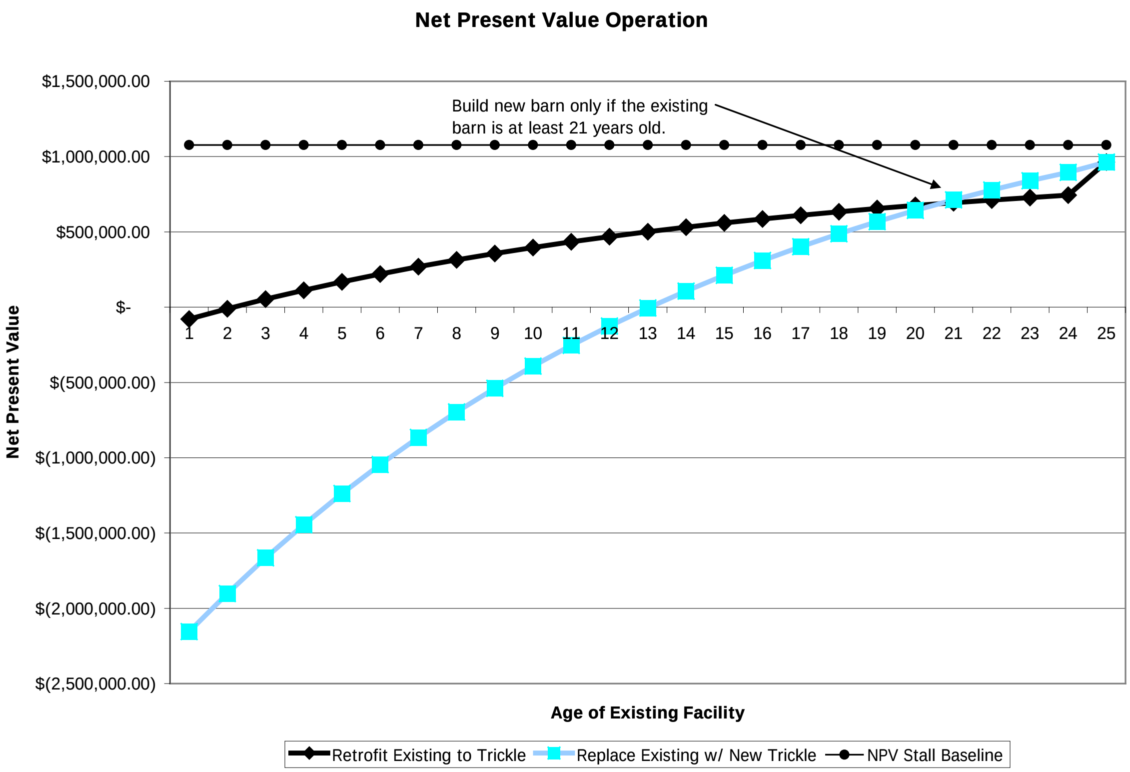

Figure 3. Retrofit or Replace Decision for Trickle Feeding

Figure 3 also shows, that retrofitting a gestation barn will still yield a positive net present value even if the barn is only three years old, while a barn must be at least thirteen years old before it make sense to replace it with a new barn. The flat line shows the net present value of continually reinvesting in an existing stall facility at the end of its useful life (not at different ages as indicated by the horizontal axis). It is higher, even at the end of its useful life, because the stalls have a lower cost of replacement than the new trickle system.

The simulation of stall replacement was completed for 2400 and 1200 sow operations and assuming barns are retrofit with a trickle feed system or replaced with new trickle feed or ESF pen based systems. In this scenario production efficiency is assumed to be unchanged and the only cost differences are the costs of replacing existing capital assets at differing time frames. Table 10 summarizes the results of the simulations on a per barn basis.

Continuing to invest in stall housing results in a three cycle NPV of $1,077,069. In other words, if an operation continued to invest in existing breeding facilities for 2400 sows for the next three life cycles of facilities (for 75 years) this would be the expected present value of that investment. A true infinite horizon NPV calculation was not implemented, because the assumption of a distribution of age of facilities would have required a different calculation for each type of barn for infinity which is quite complex. For comparison, the true infinite horizon NPV was reported previously as $1,083,848; a very close approximation because values become very small when discounted beyond 75 years.

By contrast, if the initial investment in stalls is at the end of its life and replaced with a new trickle feed system of small pens, the three-cycle NPV would be $963,312. The lower net present value is due simply to the added cost of the trickle feed system that requires extra square footage. The 11% increase in the cost of production for the breeding and farrowing sector represents only about a 3% cost increase for entire pork industry including wean- finish operations. This value is consistent with previous research and represents the best possible outcome where a policy requires pen conversion only when existing facilities are fully depreciated at the end of their useful life. However, any restrictions imposing more rapid transition such as state laws or customer mandates will result in higher costs as newer facilities are converted before the end of their useful life.

Moving down through the scenarios shows the dramatic impact that any policies that speed up transition to pen based gestation will have. For example, if a conversion is required when a barn is 15 years old a retrofit strategy to trickle feeding would result in a three cycle NPV for a 2400 sow facility of $559,185.68 and a three cycle NPV of $212,185 for abandoning the stall barn and building a new trickle feed barn, an increase in costs to the pork producer of 48% and 80% respectively. As the time frame for conversion to pens is reduced the cost of conversion increases dramatically as new investment is made in the pen facility but the cash flows from the facility do not change.

Table 10. Infinite Horizon Net Present Value Analysis of Gestation Stalls Compared to Group Pen Gestation Housing: Assume Only Capital Cost Effects

Scenario	Trickle Feed Small Pens (Per Barn) 2400 Sow Three Cycle NPV[a]	1200 Sow Three Cycle NPV[a]	2400 Sow Percent Change NPV	1200 Sow Percent Change NPV
Continue Stall Housing	$ 1,077,068.89 [c]	$ 539,674.81		
Build New Trickle Feed Pen @ 25 years	$ 963,312.22	$ 482,796.47	-11%	-11%
Retrofit to Trickle Feed Pen @ 15 years	$ 559,185.68	$ 258,632.53	-48%	-52%
Retrofit to Trickle Feed Pen @ 5 years	$ 168,334.14	$ 41,832.07	-84%	-92%
Retrofit Trickle Feed Pen Average All Ages	**$ 451,780.90**	**$ 199,056.44**	**-58%**	**-63%**
Build New Trickle Feed Pen @ 15 years	$ 212,185.40	$ 107,233.07	-80% [b]	-80%
Build New Trickle Feed Pen @ 5 years	$ (1,238,042.43)	$ (617,880.85)	-215%	-214%
Build New Trickle Feed Pen Average All Ages	**$ (216,266.96)**	**$ (106,993.11)**	**-120%**	**-120%**

Scenario	ESF Feed Large Pens (Per Barn) 2400 Sow Three Cycle NPV[a]	1200 Sow Three Cycle NPV[a]	2400 Sow Percent Change NPV	1200 Sow Percent Change NPV
Continue Stall Housing	$ 1,434,053.54 [c]	$ 718,150.28		
Build New ESF Feed Pen @ 25 years	$ 1,483,780.60	$ 729,708.93	3%	2%
Build New ESF Feed Pen @ 15 years	$ 941,474.47	$ 445,040.32	-34%	-38%
Build New ESF Feed Pen @ 5 years	$ (105,575.68)	$ (104,579.73)	-107%	-115%
Build New ESF Feed Pen Average All Ages	**$ 632,136.10**	**$ 282,661.69**	**-56%**	**-61%**

[a] Three cycle NPV assumes that three barn replacement cycles occur spanning 75 years. Insignificant differences occur compared to infinite horizon problems.

[b] The 1200 sow and 2400 sow units have the same change in this case because investment costs were assumed to be a percent mark-up compared to the base stall barn. With the retrofit or ESF specific costs per sow were included causing non-proportional changes.

[c] The base stall barns differ because in the case of ESF, the respective contractors for the trickle and ESF barns provided their own stall barn estimates as well. This allowed for a better comparison in the changes from stall to their type of system assuming same material suppliers, labor, etc.

Another implication of the differential cost impacts by age of facilities is the differential impact it may have on producers based on the age of their existing barns. The model assumption is that barns are uniformly distributed by age so that all producers are equally affected. However, impacts by age of facility clearly show that those swine production operations that have older facilities on average than the rest of the industry will have a competitive advantage in any transition because they're transitioning older barns which will represent a lower cost of transition. This structural difference may occur across firms or regionally.

Similar conclusions are reached for ESF facilities. One key difference is that no cost estimates for retrofitting using ESF are provided because it's nearly always more beneficial to just build new according to the contractor. In fact, at life-end it makes positive economic sense to transition to an ESF barn from a traditional stall barn because the three cycle NPV at life-end for an ESF in a 2400 sow setting is $1,483,780 compared to $1,434,053 for the comparable stall barn. This is mainly due to lower construction costs with less penning and concrete, less feeding equipment and the same footprint as stall barns as described earlier. However, any policy which requires conversion to ESF or pens in general prior to the end of the life of existing stall barns, results in a loss to the pork sector.

Although it appears that a new ESF barn dominates a new trickle feeding barn on a capital basis, neither system has been extensively tested in commercial applications. While trickle feeding has a higher up front cost, it likely has lower maintenance costs due to less complicated equipment as reported by survey respondents. Over the long run operational efficiencies are very important as will be shown in scenarios with changes in productive efficiency changes. In those scenarios additional maintenance and operation costs associated with ESF systems are included. Secondly, retrofitting to trickle feed systems represents the most efficient capital use for newer barns that have a long productive life remaining after conversion similar to the situation shown in Figure 1. Readers are strongly cautioned not to use these results for investment decisions as the on-the-ground circumstances can dramatically affect profitability.

Capital Plus Productivity Differences Scenarios

Although prior research and interviews suggested no clear quantifiable impact on production efficiency, respondents noted that it is more difficult to manage sow condition in group pen situations and that there is significant aggressive behavior that must be managed. They also noted that there was a greater possibility of having catastrophic losses in pens as compared to gestation stalls. For example, in the first ten months of operation of a new ESF site by one respondent, death loss of sows was reported as more than double other stall facilities.

PigCHAMP distributions of benchmark performance data is used to illustrate the potential management risk in stall facilities. Farrowing rate, which is a variable that is consistently lower for pens compared to stalls by respondents, has a range in the upper 10 percentile of producers in PigChamp of 86.6 percent to the lower 10^{th} percentile of 70 percent. If experienced producers responding to the survey are not capable of reaching the upper 10^{th} percentile of stalls using pens, what will be the impact in the industry among the lower 10^{th} percentile? Therefore, it's logically unreasonable to expect an entire industry to transition to a new form of gestation which is unfamiliar to herds-people in a short period of time and not have significant impacts on productivity.

Further, productivity has been highly dependent on barn design. It is not clear what the best barn designs are, so it is likely that productivity will suffer at least in the short run. As another example, the Oregon legislation specifically stated that sows could not be in stalls for more than 48 hours. According to respondents 32 days in stalls was necessary for breeding and settling and so restrictive regulations could significantly impact productivity as well.

Unlike capital costs, any reduction in productivity may be reflected throughout the life of the operation, resulting in greater overall impacts. The productivity changes are based on data obtained from the interviews and shown in Table 11.

In all cases the values are based on actual worst case experiences reported by survey respondents. One of the most consistent impacts was the reduced farrowing rate. Labor was increased by an amount reported by one respondent. The maintenance and repair information was based on the report of the trickle feed contractor (who had experience with ESF facilities). This rate may be as high as greater experience is gained. As describe earlier, changes in parameters were highly variable, but these serve as a benchmark of worse case outcomes on productivity. Note that they are all well above the lower 10^{th} percentile of PigChamp data indicating they're well within the realm of possibility in a new production system.

Table 11. Variables Affected by Productivity Changes to Pens

Variable	Value under Pens	Percent Change from Stalls
Sow Mortality	8.54%	22% increase
Farrowing Rate	79%	5% decrease
Total Pigs Born Per Litter	11.5 pigs	4% decrease
Stillborn Pigs Per Litter	0.42 pigs	17% decrease
Labor	$9.08/ weaned pig	15% increase
Genetics Charge	$7.12 /weaned pig	22% increase
Sow Death Loss Charge	$0.68/weaned pig	5% increase
Maintenance and Repair[a]	$3.38/weaned pig	75% increase

[a]Assumed only for ESF facilities due to complexity of equipment.

Two sets of scenarios are completed. The first scenario is a scenario based on the assumption that the productivity impacts occur only for two years and then the pen based gestation facilities perform equal to stall facilities. This transition scenario is based on one respondent's information that 2-3 turns of the barn were required to work out many of the technical problems and also accounts for additional time during which productivity may be reduced due to retrofitting and repopulating gilts into the system. Essentially this is a two year learning and training curve. Capital costs are assumed to be identical to the scenarios with only capital cost changes. This two year transition scenario is the most likely scenario to occur with an industry-wide move to gestation to pen housing from stalls. Results are shown in Table 12 and are similar in interpretation to those in Table 10. Note that a key difference is that the ESF facility results in greater total losses to the industry, this is because it is now assumed that maintenance costs are higher for ESF facilities due to the complexity of equipment.

The worst case scenario is that in addition to capital costs, the productivity of pen based systems is reduced relative to the stall systems throughout the system life. The results of this scenario are shown in Table 13. Persistent productivity impacts outweigh capital costs because the productivity impacts are incurred every period whereas the capital costs are eventually amortized. The only way to justify the transition with productivity loses is to allow conversion after all existing assets have reached the end of their useful life.

Table 12. Infinite Horizon Net Present Value Analysis of Gestation Stalls Compared to Group Pen Gestation Housing: Capital and 24 Month Transition Period

Scenario	Trickle Feed Small Pens (Per Barn): 2400 Sow Three Cycle NPV[a]	1200 Sow Three Cycle NPV[a]	2400 Sow Percent Change NPV	1200 Sow Percent Change NPV
Continue Stall Housing	$ 1,077,068.89 [c]	$ 539,674.81		
Build New Trickle Feed Pen @ 25 years	$ 851,195.37	$ 426,731.80	-21%	-21%
Retrofit to Trickle Feed Pen @ 15 years	$ 338,634.86	$ 170,445.50	-69%	-68%
Retrofit to Trickle Feed Pen @ 5 years	$ (265,522.70)	$ (131,645.17)	-125%	-124%
Retrofit Trickle Feed Pen Average All Ages	**$ 168,129.57**	**$ 85,189.34**	**-84%**	**-84%**
Build New Trickle Feed Pen @ 15 years	$ (8,365.41)	$ (3,054.64)	-101% [b]	-101%
Build New Trickle Feed Pen @ 5 years	$ (1,671,899.26)	$ (834,833.46)	-255%	-255%
Build New Trickle Feed Pen Average All Ages	**$ (499,918.27)**	**$ (248,834.58)**	**-146%**	**-146%**

Scenario	ESF Feed Large Pens (Per Barn): 2400 Sow Three Cycle NPV[a]	1200 Sow Three Cycle NPV[a]	2400 Sow Percent Change NPV	1200 Sow Percent Change NPV
Continue Stall Housing	$ 1,434,053.54 [c]	$ 718,150.28		
Build New ESF Feed Pen @ 25 years	$ 1,190,899.95	$ 583,242.24 [d]	-17%	-19%
Build New ESF Feed Pen @ 15 years	$ 359,468.83	$ 153,985.63	-75%	-79%
Build New ESF Feed Pen @ 5 years	$ (1,256,333.94)	$ (680,060.87)	-188%	-195%
Build New ESF Feed Pen Average All Ages	**$ (118,118.77)**	**$ (92,532.45)**	**-108%**	**-113%**

[a] Three cycle NPV assumes that three barn replacement cycles occur spanning 75 years. Insignificant differences occur compared to infinite horizon problems.

[b] The 1200 sow and 2400 sow units have the same change in this case because investment costs were assumed to be a percent mark-up compared to the base stall barn. With the retrofit or ESF specific costs per sow were included causing non-proportional changes.

[c] The base stall barns differ because in the case of ESF, the respective contractors for the trickle and ESF barns provided their own stall barn estimates as well. This allowed for a better comparison in the changes from stall to their type of system assuming same material suppliers, labor, etc.

[d] ESF impacts include a 75% increase in equipment maintenance costs which is why this value is higher relative to trickle feed options in this case.

Table 13. Infinite Horizon Net Present Value Analysis of Gestation Stalls Compared to Group Pen Gestation Housing: Capital and Productivity Costs

	Trickle Feed Small Pens (Per Barn)			
Scenario	2400 Sow Three Cycle NPV[a]	1200 Sow Three Cycle NPV[a]	2400 Sow Percent Change NPV	1200 Sow Percent Change NPV
Continue Stall Housing	$ 1,077,068.89 [c]	$ 539,674.81		
Build New Trickle Feed Pen @ 25 years	$ 107,515.41	$ 54,850.35	-90%	-90%
Retrofit to Trickle Feed Pen @ 15 years	$ (1,153,381.64)	$ (597,746.62)	-207%	-211%
Retrofit to Trickle Feed Pen @ 5 years	$ (3,229,630.42)	$ (1,657,339.68)	-400%	-407%
Retrofit Trickle Feed Pen Average All Ages	**$ (1,759,363.12)**	**$ (1,070,085.33)**	**-263%**	**-298%**
Build New Trickle Feed Pen @ 15 years	$ (1,500,381.90)	$ (749,146.07)	-239% [b]	-239%
Build New Trickle Feed Pen @ 5 years	$ (4,636,006.97)	$ (2,317,052.58)	-530%	-529%
Build New Trickle Feed Pen Average All Ages	**$ (2,427,410.96)**	**$ (1,212,688.40)**	**-325%**	**-325%**

	ESF Feed Large Pens (Per Barn)			
Scenario	2400 Sow Three Cycle NPV[a]	1200 Sow Three Cycle NPV[a]	2400 Sow Percent Change NPV	1200 Sow Percent Change NPV
Continue Stall Housing	$ 1,434,053.54 [c]	$ 718,150.28		
Build New ESF Feed Pen @ 25 years	$ 392,876.91	$ 184,055.85 [d]	-73%	-74%
Build New ESF Feed Pen @ 15 years	$ (1,241,574.09)	$ (646,886.67)	-187%	-190%
Build New ESF Feed Pen @ 5 years	$ (4,437,038.52)	$ (2,271,110.16)	-409%	-416%
Build New ESF Feed Pen Average All Ages	**$ (2,186,459.54)**	**$ (1,127,156.07)**	**-252%**	**-257%**

[a] Three cycle NPV assumes that three barn replacement cycles occur spanning 75 years. Insignificant differences occur compared to infinite horizon problems.

[b] The 1200 sow and 2400 sow units have the same change in this case because investment costs were assumed to be a percent mark-up compared to the base stall barn. With the retrofit or ESF specific costs per sow were included causing non-proportional changes.

[c] The base stall barns differ because in the case of ESF, the respective contractors for the trickle and ESF barns provided their own stall barn estimates as well. This allowed for a better comparison in the changes from stall to their type of system assuming same material suppliers, labor, etc.

[d] ESF impacts include a 75% increase in equipment maintenance costs which is why this value is higher relative to trickle feed options in this case.

Aggregate Industry Economic Impacts

The results in Tables 10, 12 and 13 show the economic impacts on a barn level basis. However, the aggregate impacts depend on the number of facilities that require retrofitting or replacement and also the age of those facilities to determine their loss of useful life.

Using the estimates of the number of barns shown in Table 7, it's possible to aggregate the costs to the industry to estimate a total expected cost of converting existing stall barns to either ESF or trickle feeding pen systems. The assumption of a uniform distribution of the age of barns is used because it avoids the need to consider the timing of any regulation requiring conversion and the average costs to the industry of a conversion can be calculated at any point in time. It's only necessary to multiply the per barn impacts by the number of facilities in each category. One shortcoming of this assumption is that does not account for the fact that it is unlikely that any new stall barns will be built once a regulation requiring phase-out. So, for example, it's doubtful any new stall barns will be built by Smithfield Foods in the next ten years due to their own stated conversion and the minimum age of their stall facilities at the time necessary to convert should be ten years. However, each age of facility is simulated independently in the spreadsheet so it is a matter of simple weighted averaging to determine any combination of scenarios which might emerge.

The aggregate industry impacts on net present value for each per barn scenario in Tables 10, 12 and 13 are shown in Table 14. For the capital cost impacts, estimates of total industry reduction in net present value range from $1.32 billion to over $2.66 billion dollars. This represents a 53 to 106 percent decrease in NPV for the industry. In the worst case scenario, where productivity losses are persistent, the potential loss to the industry is a maximum of $7.49 billion. However the mostly likely case is the increased capital costs with a two year productivity transition or an aggregate loss of about $3.2 billion to the pork industry.

Table 14. Aggregate Industry Level Net Present Value Differences of Gestation Stalls Compared to Group Pen Gestation Housing

Scenario	Capital Cost Impacts: 2400 Sow Three Cycle NPV[a]	1200 Sow Three Cycle NPV[a]	Total Industry Cost	Percent Decrease in Industry NPV[b,c]
Total Average Cost to Retrofit Barns to Trickle Feed	$ 856,644,598.04	$ 466,647,186.91	**$ 1,323,291,784.96**	53%
Total Average Cost to Build New Trickle Feed	$ 1,771,870,117.99	$ 885,935,059.00	**$ 2,657,805,176.99**	106%
Total Average Cost to Build New ESF Feed	$ 1,098,643,078.01	$ 596,619,354.92	**$ 1,695,262,432.93**	51%

Scenario	Capital and 24 Month Productivity Transition Period Cost Impacts: 2400 Sow Three Cycle NPV[a]	1200 Sow Three Cycle NPV[a]	Total Industry Cost	Percent Decrease in Industry NPV[b,c]
Total Average Cost to Retrofit Barns to Trickle Feed	$ 1,245,246,904.39	$ 622,645,119.35	**$ 1,867,892,023.74**	74%
Total Average Cost to Build New Trickle Feed	$ 2,160,472,424.34	$ 1,080,257,879.32	**$ 3,240,730,303.66**	129%
Total Average Cost to Build New ESF Feed[e]	$ 2,126,476,145.03	$ 1,110,635,372.36	**$ 3,237,111,517.39**	97%

Scenario	Capital and Permanent Productivity Reduction Cost Impact: 2400 Sow Three Cycle NPV[a]	1200 Sow Three Cycle NPV[a]	Total Industry Cost	Percent Decrease in Industry NPV[b,c]
Total Average Cost to Retrofit Barns to Trickle Feed	$ 3,885,911,942.88	$ 1,981,449,761.07	**$ 5,867,361,703.95**	244%
Total Average Cost to Build New Trickle Feed	$ 4,801,137,462.83	$ 2,400,737,633.16	**$ 7,201,875,095.99**	286%
Total Average Cost to Build New ESF Feed[e]	$ 4,960,102,904.13	$ 2,528,069,682.53	**$ 7,488,172,586.66**	224%

[a] Three cycle NPV assumes that three barn replacement cycles occur spanning 75 years. Insignificant differences occur compared to infinite horizon problems.

[b] The percent increase in cost (decrease in NPV) will be used in partial equilibrium simulation model to estimate market price and quanity impacts in the pork industry.

[c] Percent changes in NPV are calculated as the industry weighted average difference in the aggregate NPV for stall faclities and aggregate NPV for the pen based facilities indicated. This includes both 2400 and 1200 sow units For example, in Table 10 the average loss for a 1200 sow facility retrofitted to a trickle feed facility is 63% and the average loss for the 2400 sow facility is 58%. The 2400 sow units represent 54% of U.S. inventories and 1200 sow units represent 34% of U.S. inventories (Table Therefore, the weighted average impact is 0.58 * 0.54 + 0.63 * 0.34 = 53%. Note the average weights sum to 88%, not 100% because the remaining 12% of production is assumed to be non-stall inventories and not subject to different costs of production.

Sensitivity Analysis of Economic Impacts

Numerous assumptions have been made to complete the economic impact analysis and in many cases the selection of parameter values was subjective due to limited information on technical impacts. To broaden the results, a sensitivity analysis is completed. The sensitivity analysis considers the effect that different values of key parameters such as farrowing rate have on the economic impact of a transition to pens. It also can be used to provide a ranking of input variables by their impact on the economic costs of transitioning to pens to provide insight into which aspects of the transition must be most carefully managed.

To conduct the sensitivity analysis the baseline model used is the 2400 sow trickle system with the cost of capital changes included. The results are proportionally equivalent in the 1200 sow models and would be redundant. ESF models are also no more or less sensitive to any impacts, but will vary only by levels. Only in cases where the sensitivity analysis is specific to factors included in one of the other models is another model used and those instances are noted.

The key outcome variable is the average net present value over all periods as were reported in Tables 10, 12 and 13. Each input variable is increased or decreased by 10 percent and then the model is run to show the impact on the change on the outcome variable of net present value. By showing a 10% change across all key variables, the relative impacts of input variables can easily be compared. Table 15 shows the numerical results of this analysis and Figure 4 shows the impacts in graphical form for easier interpretation.

Total pigs born per litter, farrowing rates and litters farrowed per breeding female per year had the greatest impacts on the net present value of the pen system. A 10% reduction in any of these variables resulted in approximately $3 million in additional losses over the life of the facilities. It clearly demonstrates that the reduction in farrowing rates consistently reported by survey respondents is a major concern for the viability of transitioning to pens if farrowing rates cannot be improved.

The facility related costs on the upper portion of Figures 4 do not have as great an impact as the production factors. This is because the facility related impacts are amortized over the life of facilities. The depreciable life of barns is significant. If the depreciable lives of actual barns are longer than the assumption of 25 years used in the model, the model will substantially underestimate cost impacts. Every 10 percent increase in depreciable life represents approximately a 130 percent reduction in the net present value over the lifetime of the facility.

Table 15. Impact of 10% Change in Input Variables on Infinite Horizon Net Present Value

			Retrofit Barn		Build New Barn	
Variable Name	**Base Value**	**10% Impact**	**NPV After 10% Impact (000s)**	**Absolute Change NPV (000s)**	**NPV After 10% Impact (000s)**	**Absolute Change NPV (000s)**
Sow Productivity Variables			**Base NPV = $451,780.90**		**Base NPV = $(216,266.96)**	
Sow Mortality Rate	7.0%	7.7%	$ 417.89	$ (33.89)	$ (250.16)	$ (33.89)
Farrowing Rate	83.3%	75.0%	$ (2,410.07)	$ (2,861.85)	$ (3,078.12)	$ (2,861.85)
Total Pigs Born Per Litter	12.0	10.8	$ (2,681.52)	$ (3,133.30)	$ (3,349.57)	$ (3,133.30)
Stillborn Pigs Born Per Litter	0.5	0.6	$ 321.23	$ (130.55)	$ (346.82)	$ (130.55)
Pre-weaning Mortality	0.5	0.6	$ 310.88	$ (140.90)	$ (357.16)	$ (140.90)
Litters Farrowed/Breeding Female/Year	2.3	2.1	$ (2,287.84)	$ (2,739.62)	$ (2,955.89)	$ (2,739.62)
Average Lactation Length	20.0	22.0	$ 354.00	$ (97.78)	$ (314.05)	$ (97.78)
Feed Intake Gestation (lbs/sow/day)	5.0	5.5	$ 29.38	$ (422.40)	$ (638.67)	$ (422.40)
Feed Intake Farrowing (lbs/sow/day)	12.0	13.2	$ 250.57	$ (201.21)	$ (417.48)	$ (201.21)
Feed Intake Gilts (lb/gilt/day)	5.0	5.5	$ 424.79	$ (26.99)	$ (243.26)	$ (26.99)
					$ -	
Facility/Capital Variables					$ -	
Investment Cost in New Trickle Feed	$ 2,223,000.00	$ 2,445,300.00	$ 377.84	$ (73.94)	$ (408.17)	$ (191.90)
Cost of Retrofit	$ 731,428.57	$ 804,571.43	$ 400.63	$ (51.15)	$ (216.27)	$ 0.00
Gestation Square Footage per Sow	20.0	22.0	$ 345.44	$ (106.34)	$ (369.79)	$ (153.52)
Discount Rate	7.0%	7.7%	$ 175.04	$ (276.74)	$ (466.81)	$ (250.54)
Depreciable Life of Facility (years)	25.0	22.5	$ 168.18	$ (283.60)	$ (498.94)	$ (282.68)
Depreciable Life of Facility (years)	25.0	27.5	$ 670.98	$ 219.20	$ 5.18	$ 221.44
Equipment Costs ($/sow)	$ 185.25	$ 203.78	$ 428.24	$ (23.54)	$ (254.65)	$ (38.38)
Maintenance and Repair ($/sow)	$ 35.63	$ 39.19	$ 330.40	$ (121.38)	$ (337.65)	$ (121.38)

Note: Base model is a 2400 sow trickle feed facility with only the cost of capital considered as transition. This allows impacting productivity values from their baseline level

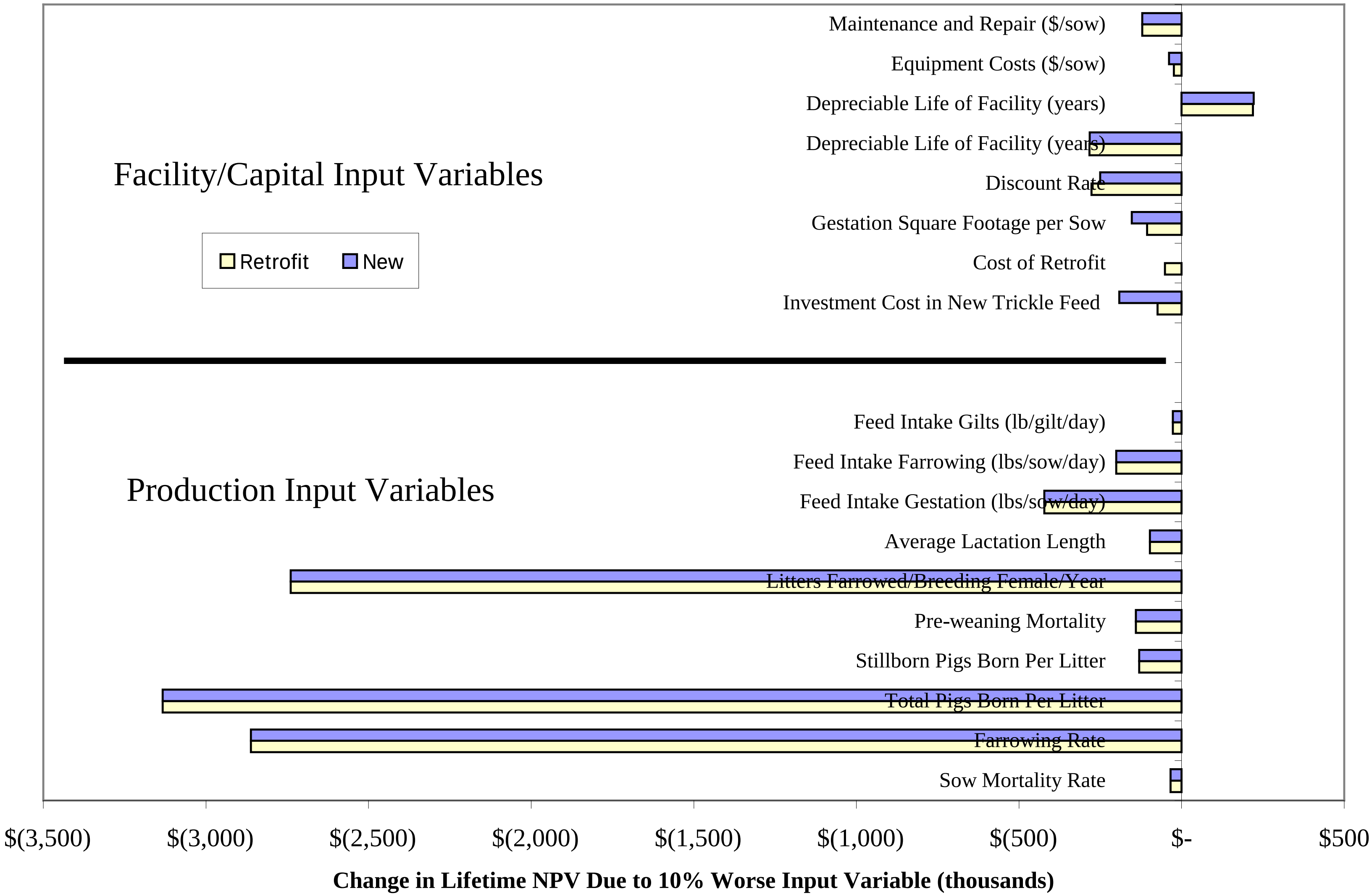

Figure 4. Absolute dollar impact of a 10% change in production/capital value on the net present value of a new trickle gestation barn.

Production performance is the most important factor impacting the economic costs of transitioning to pens. An important underlying issue is whether any production performance problems can be overcome in a short time period or if they are persistent. In the base analysis the learning curve was assumed to be 2 years, but this can vary. Therefore, a sensitivity analysis of the length of time to learn to operate the pen facilities is completed by increasing the learning time by 10% (from 24 months to 26.4 months) and the net present value was re-evaluated. This required the use of the 2400 sow model including productivity impacts as well as capital costs which is why this learning sensitivity analysis is not completed with the same model for the initial sensitivity analysis. The results show that for a new 2400 sow trickle barn, a 10% increase in the time to learn how to manage a new system results in a 3.3% reduction in the net present value of the facility or a loss of approximately $16,500. These results would be consistent across other systems.

A key factor affecting overall industry profitability is the distribution of the age of facilities in the industry. The baseline assumption is that facility age is uniformly distributed meaning there are an equal number of all ages of barns in the industry. This is a reasonable assumption if one assumes a model of straight-line depreciation in perpetuity. However, we observe cycles of investment and divestiture in the swine industry and surges in replacement based on new technologies (e.g., three site production with separate wean and finish sites has evolved to two-site production with wean-finish facilities being a single unit). It is not known what the true age distribution is but we can simulate what happens if we change the age distribution of barns. As before, the sensitivity analysis begins with the assumption that the mean of the distribution of the age of barns is 10% lower than average. If barns that are stalls range between the ages of new and 25 years, this would mean the average age of barns is 12.5 years and a 10% reduction in the average age would mean barns average 11.25 years old. To reduce the average age to 11.25 years, the barns must be distributed so that they are skewed towards newer barns. A log-logistic distribution as shown in Figure 5 was used for the simulation. With the baseline uniform distribution each age category of barns would contain 4% ($1/25^{th}$) of the barn inventories. In the log-logistic case, the percentage of barns in any age category varies.

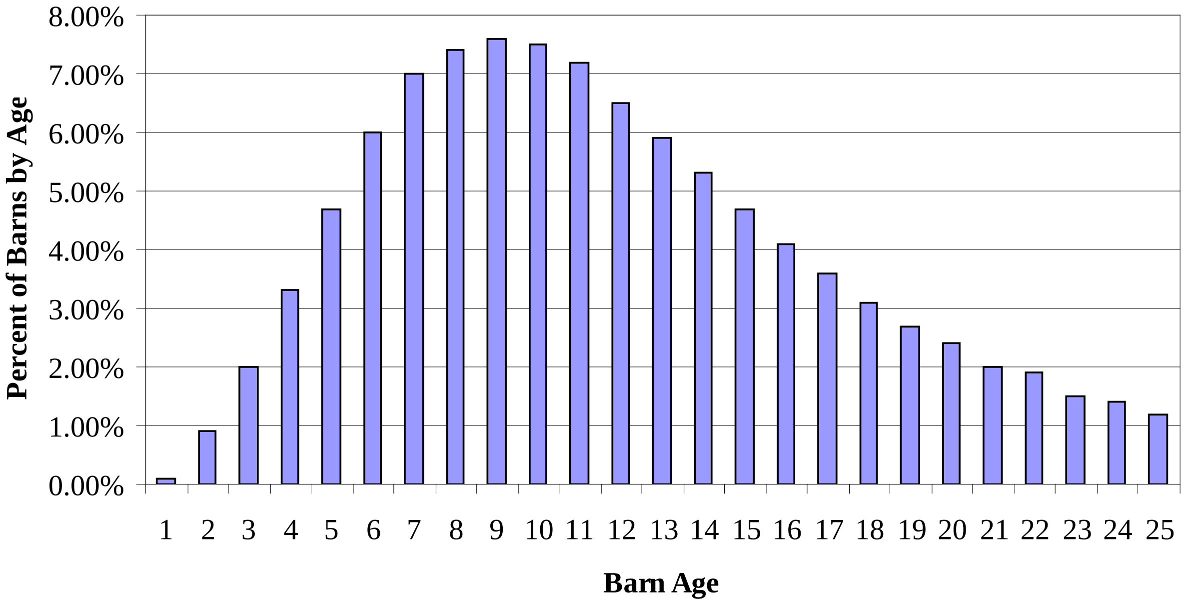

Figure 5. Assumed Log-Logistic Distribution with 10% Age Shift to Newer Barns.

For the analysis, the age distribution of barns does not affect the base net present value calculations on a per barn basis, rather it affects the total cost to the industry of the transition and the average net present value cost for the industry. To calculate the average net present value it's necessary to calculate the sum of the products of the net present value of each age category by the number of barns in that category based on the log-logistic distribution. This number can then be divided by the total number of barns to arrive at the average age distributed net present value. Completing this analysis shows that a reduction in the average age of barns by 10% results in a reduction in the average net present value for retrofitting a 2400 sow trickle barn by $21,684 on average and a reduction in the average net present value for building a new 2400 sow trickle barn by $59,504. In percentage terms, a 10% reduction in barn age results in a 4.8% reduction in net present value from retrofitting, but a 27.5% reduction in net present value for building a new barn. This again illustrates the earlier conclusion that if barns are newer then retrofitting is a preferred alternative if possible.

For comparison, the same age distribution assumptions were made for a 2400 sow ESF barn and showed that a 10% reduction in the average age distribution of barns resulted in a $42,962 reduction in the net present value of the pen barns relative to stall facilities.

Production Parameter Variation and Result Sensitivity

A second method of evaluating the sensitivity of the model is to conduct a risk simulation dependent on the observed variability of key production variables. This can better show the distribution of possible outcomes based on observed production parameters. Probability distributions for production variables were obtained from PigChamp benchmark data which shows both the mean and standard deviation of key variables. The mean and standard deviation are sufficient to construct a normal distribution of the variables, which may not be their true distribution, but the underlying data was unavailable. The actual means of observed data from PigChamp did not match the means of the original production variables in the model because they were taken from other sources. Therefore, to be able to use the original variables, it was necessary to convert the reported standard deviations from PigChamp to the means of the variables in the model. This was done by first calculating the coefficient of variation (standard deviation/mean) from the PigChamp data and then calculating the estimated standard deviation for the variable used in the model (standard deviation = c.v.*model variable). The production variables simulated and their values are shown in Table 16.

Table 16. Variation of Production Variables for Risk Simulation

Item	PigChamp Mean	PigChamp Std. Dev.	PigChamp Coeff. Var.	Model Value	Implied Std. Dev.
Annual Cull Rate: Breeding Females (%)	53.10%	55.19%	104%	40%	41.57%
Annual Mortality Rate: Breeding Females (%)	8.84%	3.78%	43%	7%	2.99%
Farrowing Rate (%)	77.43%	10.93%	14%	83%	11.76%
Total Pigs Born Per Litter (head)	11.99	0.75	6%	10.5	0.65
Stillborn Pigs/Litter (head)	0.94	0.31	33%	0.6	0.19
Pigs Born Alive/Litter (head)	10.69	1.29	12%	9.9	1.19
Pre-Weaning Mortality (head)	1.29	0.94	73%	0.8	0.56
Weaned Pigs Per Litter (head)	9.30	1.15	12%	9.1	1.13
Litters Farrowed / Breeding Female / Year	2.33		10%	2.3	0.23

Source: PigChamp Benchmarking accessed at http://www.pigchamp.com/benchmarking.html, United States, 2006 Annual

The first three numerical columns show the values obtained directly from PigChamp information. The variability of many of the variables is quite high suggesting a very wide distribution of results. The two shaded columns show the values used for the risk simulation of the impacts of alternative sow housing investments.

To simulate the impacts of variability of production variables, @Risk simulation software for Excel was used. The actual statistical distributions of the variables are unknown, but the mean and standard deviation can be used to fully specify a normal distribution for each of the variables. @Risk basically re-estimates the results for each draw of a variable from its normal distribution, in this case 5,000 draws were used due to the very large observed variation in variables. As an overall analysis, all production variables in Table 16 were included and simulated simultaneously. Thus, the overall distribution of outcomes on the net present value of investment was calculated for the stall facility, a retrofit facility and investment in a new trickle facility. Figure 6 shows the distributions of the net present value for continuing with a stall facility, retrofitting a facility to pens and building a new trickle facility for 2400 sows. The results are based on the same assumptions as the original analysis, the only change is to include variation in production variables to observe the overall distribution of production.

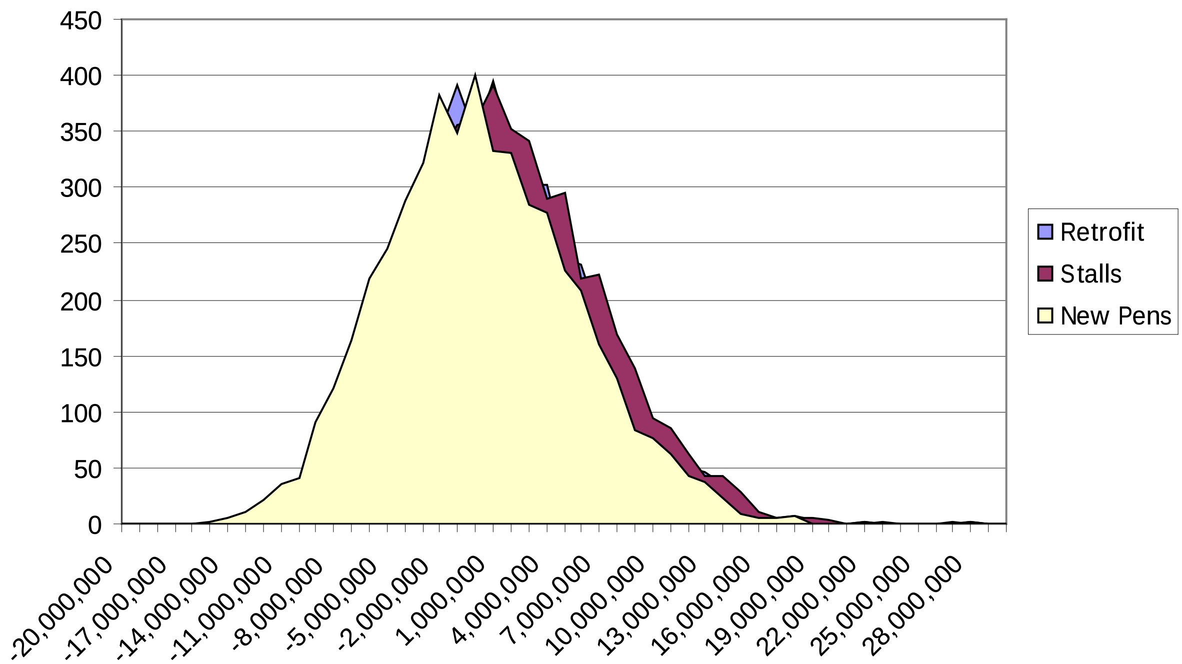

Figure 6. Distribution of net present values based on observed variation of production values shown in Table 16.

As expected the distribution for building new trickle pens shifts the distribution of net present value to the left, or lower, relative to continuing to use gestation stalls. No difference in variation is assumed between the alternatives, so this simulation simply shows how variable net present values are for the alternatives. The variability is quite remarkable, ranging from approximately a positive NPV of $25 million to a negative NPV of as much as -$15 million (note that the means are the same as reported in Tables 10-13). One hypothesis for why this distribution is so wide, is that it includes production facilities which have disease pressure, although this would not explain the top end of the distribution. Never-the-less, this shows the significant sensitivity of existing stall systems to variation in productivity. The critical point is that if group pen gestation facilities are in fact even more susceptible to variation than the stall systems, it's not unrealistic to expect similar or even wider distributions of outcomes. It's informative to consider that even with deep experience in stall systems that this amount of variation exists – how much more will management of unknown facilities impact the transition to pens?

In surveys of producers with existing pen facilities, farrowing rate was identified as a key variable impacted by the switch to pens. Figure 7 shows the effect that the observed variation in farrowing rates has on the net present value of a new pen facility.

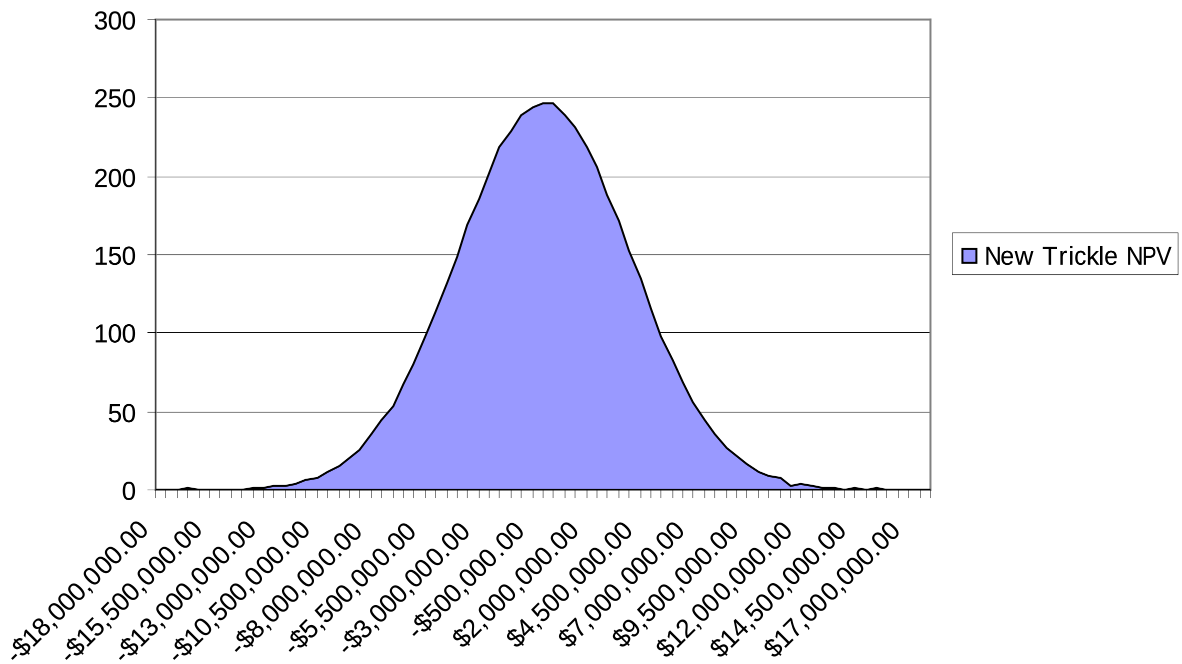

Figure 7. Impact of variation in farrowing rate on the NPV of a new trickle pen facility.

The distribution is perfectly normal, because it is simulated as a normal distribution with only farrowing rate variation included. This further demonstrates that farrowing rates have an outsized potential impact on net present value of facilities and therefore raises a substantial concern regarding the reduced farrowing rate already observed in the implementation of pen facilities. Therefore, this sensitivity analysis suggests that efforts should be focused on improving farrowing rates in sows housed in group pens and identifying the underlying causes of those reduced rates. Failure to do so may substantially increase losses to the industry.

In summary, the sensitivity analysis shows that minor changes in production assumptions and particularly in sow productivity variables can have substantial impacts on profitability. Further, actual production data shows that there are substantial risks in stall facilities, and if pens increase this risk exposure the potential downside risk is 2-3 times the magnitude of the losses projected under baseline productivity assumptions.

Direct Consumer Demand Impacts of Animal Welfare

The primary incentive for the removal of gestation stalls is usually described as consumer demand for animal friendly practices. If consumers do prefer pork products raised using animal friendly practices, there exists the potential for recovery of costs through increased prices of meat products.

Animal welfare attributes are an example of credence attributes for consumer demand. Credence attributes are not observable in the product itself. For example, teriyaki marinated pork tenderloin is clearly observable to the consumer and can be verified upon consumption. Credence attributes can only be verified by the consumer at extreme cost and not by direct observation of the product. Attributes such as animal welfare, environmentally friendly, organic, natural, and country of origin are credence attributes.

One consumer aspect of animal welfare that may differ from other credence attributes is the ‘moral intensity’ of the issue. People have relatively strong opinions regarding animal welfare. Moral intensity attributes tend to exhibit a very high value for those people who hold those attributes as important but for others who don’t share the same values they may be willing to pay nothing (Bennett, Anderson and Blaney). This is in contrast to issues such as food safety where nearly all consumers will be willing to pay a positive value for some improvement. This also has important policy consequences. If a regulation such as a national ban on gestation stalls affects all production, costs will rise for all consumers, even the majority who may have no personal willingness to pay. Better policies for supporting all consumers' welfare regardless of preferences include labeling and certification of practices, rather than mandates so that each consumer segment can make the choice to support its own preferences..

Few studies have assessed demand for animal friendly rearing practices in the U.S. Much of the literature originates in Europe where the issue has gained much greater prominence. Those studies conducted in Europe should be interpreted with extreme caution in extrapolating to the U.S. because there are clear differences in attitude exhibited by key food policy issues. For example, Europe maintains bans on the use of growth promotants in livestock. Several countries have implemented bans on sub-therapeutic antibiotics, and several have already placed policy restrictions on animal rearing methods. Clearly, the political and consumer climate differs greatly from the U.S. However, they may provide useful information as a proxy for the maximum one might expect consumers to pay for animal welfare practices.

Two recent papers from a survey by Meuwissen, van der Lans and Huirne (2004) and Meuwissen and van der Lans (2004) provide perhaps the most comprehensive insight into consumers' willingness to pay for animal welfare attributes in pork products. The basis for the results is a customized conjoint analysis survey. A conjoint analysis asks respondents a series of questions regarding product attributes typically in combination with each other. The survey was conducted in 2001 in the Netherlands and there were 1,444 respondents. Their results showed that respondents were willing to pay between 35 and 82 percent more for 'animal friendly' products. However, 45% of respondents (513) were actually concerned about pork production issues and only 43% (221) of those were concerned about animal friendly practices. A relatively small number of respondents (221 out of 1,444) are concerned about animal friendly practices, but they are willing to pay a large amount. Accounting for those not willing to pay extra, the average willingness to pay for animal friendly practices averaged 30.9 percent. Another interesting issue raised is the ranking of pork production attributes. The surface upon which pigs are raised (bedding, concrete, grids, or sand) was the third most important attribute for consumers, only less important than the price and quality of pork. However, practices that actually cause direct physical stress (teeth clipping, castration and docking tails) ranked 21-23 in terms of most important issues. Perhaps consumers recognize that the lifelong conditions of facility type although not an acute welfare issue is a chronic issue potentially affecting quality of life.

Grannis and Thilmany (2000 and 2002) surveyed 1,400 consumers in Colorado, Utah and New Mexico regarding their attribute preferences for pork products. Their primary focus was on the willingness to pay for 'natural' products, but they questioned consumers regarding their ranking of concerns regarding the use of hormones and antibiotics, the environmental impacts on streams, the environmental impact on endangered species, the pen size in which pigs are raised (the sole measure of welfare), and whether the product was grass-fed (the survey included beef too) and whether it was raised locally. The attribute of pen size ranked fifth with a score of 3.03 on a scale where 1 was no concern and 5 was extremely concerned. Pen size ranked behind hormones, antibiotics and environmental issues. An analysis of the willingness to pay for pigs raised in large pens showed that consumers were willing to pay on average 18 percent more for pigs raised in large pens, but this value was insignificant for pork chops and significant for ham.

A study by Hurley and Kliebenstein provides insights into consumers' willingness to pay for environmental attributes in pork products. There is no direct reference to animal welfare in the manuscript, but environmental attributes are similar to animal welfare attributes in that they likely do not directly affect the pork eating experience (may not be the case for welfare –e.g., less bruising in handling) and is a credence attribute. Hurley and Kliebenstein conducted experimental auctions in several U.S. locations. They auctioned pork products that were conventional or had claims of being raised under conditions that protected surface water, ground water or reduced odor emission, and combinations of those attributes including a product that combined all three environmental characteristics. Their results showed that there were no regional differences in willingness to pay. The average willingness to pay for the combined attributes was a 22 percent increase compared to the reference price. For those participants in the experiments with a positive willingness to pay, the average willingness to pay was 37 percent. Of all participants, 38 percent were unwilling to pay any premium for environmentally assured pork products.

Significant attention has recently focused on consumer willingness to pay for country of origin labeling in meats. COOL is an issue addressing meat demand and it is an attribute that will require similar assurances of a credence attribute. Although particular values may not be directly applicable some of the recent insights into consumer behavior may help guide possible scenarios and considerations of the impacts of animal welfare. As cited in Umberger (2004), Loureiro and Umberger (2003) surveyed 243 Colorado consumers at supermarkets and found they were willing to pay 38-58 percent more to obtain certified U.S. steak and hamburger. In Loureiro and Umberger, they suggest that the higher value for hamburger may simply be due to the lower starting price of hamburger in making the comparison. They did not address pork and it is worth noting that this may be significantly different from pork due to the absence of a BSE like issue related to the origin of beef cattle. Loureiro and Umberger (2003) also point out that there is a demand effect to the premiums for labeling. They report that as the premium required increases, the probability of paying the premium decreases. For example, as the premium for 'certified U.S. steak' increased by $0.01/lb., the probability of paying the premium decreases by 0.001.

Also cited in Umberger is a study conducted by Umberger et al. (2003) which relied on experimental methods and survey procedures and determined that 73% of consumers indicated a willingness to pay average premiums of 11 percent for steak and 24 percent for ground beef with COOL labeling. Umberger also sites a third study by Loureiro & Umberger that continental U.S. consumers were willing to pay average premiums of 2.5-2.9% over the original market price to obtain "certified U.S." chicken breasts, pork chops and rib eye steaks. Umberger points out that these values may not be interpreted to be values paid at actual retail stores. Partially because of the inherent hypothetical nature of surveys and experiments, but also because in store, the customer will face a broader array of trade-offs as well as the inherent effect that supply and demand will have on prices. For example, Umberger points out that if the supply of beef labeled "certified" U.S. exceeds the demand of those willing to pay more for this beef, this will mitigate any potential premium affect.

Previous studies suggest there may be a positive willingness to pay for animal welfare specifically and other credence attributes more generally. Estimates of willingness to pay across all consumers ranged from 18 percent to 30 percent. These results will not be included directly in the simulation, but rather the simulation of market impacts will be used to calculate how much consumers must be willing to pay in order to compensate for restrictions on the use of stalls. Table 15 provides a tabular summary of the key results of the reviewed literature. One key shortcoming is that no study specifically addresses consumer willingness to pay for pen versus stall housing.

Market Adjustment Impacts with Transition to Group Sow Housing

Given the level of impacts a transition from stalls to pens is expected to have on the breeding sector of the pork industry, it's clear that market prices and quantities will adjust to this change. These market level impacts are well known as pointed out by Gardner (2003) in regard to animal welfare practices. He goes further to suggest from previous observations of major cost impacts in agriculture that buyers (consumers) will bear the majority of the costs impacts in the case where production is more price-responsive than demand. Following is an estimation of the market level impacts of a move to pen based housing using the percent change in cost (or equivalently NPV) estimates shown in the final column of Table 14. This assessment includes the distribution of impacts on consumers and producers and the necessary increase in willingness to pay by consumers to compensate the pork industry for the transition to pens.

Partial Equilibrium Model for Estimating Market Impacts of a Transition to Group Housing

The equilibrium displacement model (EDM) which originated with Muth has been widely adopted in agricultural economics for policy analysis (Wohlgenant (1993), Chung and Kaiser (1999), Duffy and Wohlgenant (1991). EDM creates a reduced form linear representation of supply, demand and marketing response based on elasticities from previously estimated econometric models of supply and demand such as in Buhr. The advantage is that the model is very easy to specify, parameters or elasticities can easily be adjusted to develop sensitivity analyses of scenarios, and economic 'shocks' such as cost increases or preference changes can be easily incorporated as shifters. The disadvantage is that the model may not be consistent if parameters drawn from different studies have different assumptions or data sets underlying their estimation.

Most recently EDM models have been used to evaluate the economic impact of country-of-origin labeling in livestock and meat (Lusk and Anderson; and Brester, Marsh and Atwood). Lusk and Anderson also incorporated an international trade sector into the model. This is included to account for the fact that if the U.S. is the only country which adopts pens relative to other pork trading countries, then the U.S. will also lose market share in world markets. Therefore, the Lusk and Anderson model provides the basis for the specification of the EDM used for this analysis, but modified to fit the situation. The model is available upon request.

Table 17. Willingness to Pay for Pork with Animal Welfare Attributes

Authors	***Product***	***Attributes***	***Method***	***WTP***	***Comments***
Hurley and Kliebenstein (1999)	Pork	Environmental: (1) surface water, (2) ground water (3) odor emissions	Experimental Auction Markets. Second-price Sealed bids.	62% paid premium	Combination of all three attributes had greatest WTP. Results are over multiple regions in US.
				No Regional Difference	38% were unwilling to pay premium, yet this cost will be imposed on them.
				Avg. prem = $.94/package (22%) package = 2 lbs. 62% payers Premium = $1.60/package(37%)	
Grannis and Thilmany (June 2000 and 2002)	Beef and Pork	Production: No Small Crowded Pens; No Antibiotics; no growth hormone; grazing managed(beef)	Survey 1400 consumers in Colorado, Utah and New Mexico	Ranking (5 being most important attribute): Hormones: 3.72 Antibiotics: 3.38 streams: 3.37 Endangered: 3.20 Pen Size: 3.03 Aged: 3 Grassfed: 2.94 local: 2.41	No values for pen size were given. Not clear what premiums might be. What about 60% of consumers unwilling to pay for natural attributes? What happens to their surplus as prices increase due to increased costs. In *Agribusiness* (2002), Table 3, have significant WTP for ham with greater pen size, but not for pork chop. This conflicting result is questionable.
Meuwissen, van der Lans& Huirne (2004)	Pork	Many production attributes. Categories: Feed, breed/GM, Farm production, Slaughter, retail/consumption.	Customized conjoint analysis, survey analysis task on computer platform. Data collected 2001, 1444 respondents, 1199 complete.	Ranking of attributes (most to least important): taste, price, living surface (straw, sand, mud, concrete, grid), (6) pig space, (10/11) Housing (inside v outside), (15) housing (group v individual). Interesting practices such as teeth clipping, castration, docking tails ranked 21-23 as issues of concern.	Most comprehensive of traits. Animal friendly segment of responders was willing to pay significantly more premiums (35-82%), but they comprise smallest segment of consumers in the segments. Survey participants are from the Netherlands, no U.S. perspective.
Meuwissen and van der Lans (2004)	Pork	Many production attributes similar to other study	Same method as other study	Animal welfare WTP=30.9 percent greater than reference price. And n=393 (64%) respondents willing to certainly pay greater than zero.	47% of respondents (513) concerned about pork production. Of this group 43% concerned about animal welfare. WTP for Animal Welfare is greater than attributes of Food safety, environmental assurance, naturalness and sensory quality -- more respondents WTP and higher value. Authors point out that not all Animal Welfare measures are consistent, issues like castration, teeth clipping, and tail docking score low. Survey participants are from the Netherlands, no U.S. perspective.

Pork Sector Impacts of Transitioning from Stalls to Pens

The impacts of alternative scenarios for the breeding sector to adapt to pens are shown in the last column of Table 14. For example the cost impact of retrofitting existing barns to trickle feed systems increases the present value of costs by 53 percent. This represents the lower bound of market impacts. At the high end is the result for the trickle feeding small group pen system with productivity losses. In that circumstance the present value of costs for the breeding herd would increase 286 percent[2].

For the simulation only the breeding herd is directly affected by the increase in costs. It is possible that some economic costs will be incurred in wean/finish operations if the number of weaned pigs produced does not effectively utilize those assets. However, the net present value model was constructed to maintain the current number of weaned pigs, so this is not analyzed. Meanwhile, the EDM model is based on the entire hog sector supply so the change in breeding herd costs must be pro-rated to the share of costs contributed by the breeding herd to the total costs of pork production. According to the Center for Farm Financial Management's FINBIN farm records database (http://www.finbin.umn.edu) the total cost of production for a market hog to an average weight of 256 pounds was $109/head. The average cost per weaned pig was calculated as about $36 per weaned pig in the case of trickle feeding and $35.60 per weaned pig for the ESF facility. Therefore, the weaned pig share of costs represents about one-third of the costs of a market hog and all percentage changes in breeding costs must be pro-rated by this amount to show their total effect on market hog production costs which is the basis of the hog supply component of the EDM model.

The best case scenario to be analyzed is the 53% decrease in net present value due to the increased capital costs of retrofitting an existing stall facility to a trickle feed pen barn. Multiplying this by one third results in and 18% assumed increase in the total costs of production for the pork sector to be included in the EDM market simulation. Similarly, the high end estimate of a 106 percent increase in breed-farrowing costs with the implementation of new trickle feed pen systems is simulated as a second capital cost increase scenario. The net pork industry production cost increase in this scenario is a one-third of 106 percent or 35 percent increase.

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[2] Although the net present value calculations include revenue from weaned pig sales, revenue is held constant for all scenarios and therefore the calculation of net present value is actually the present value of costs and the percent changes are in fact the percent change in costs.

The second set of impacts modeled will assume the use of an ESF feeding system with new barn facilities and including productivity losses. The most likely scenario is the case when there is a transition period of reduced productivity from pen housing, after which the industry productivity returns to that of stall housing. For this scenario the ESF case in Table 14 is used which results in a 97 percent decrease in net present value to the breeding herd or a 32 percent increase (breeding and farrowing costs account for one-third of the total costs of hog production as described earlier) in costs to produce a market hog. The high end of potential productivity losses result when the productivity loses are persistent so that the breeding and farrowing net present value decreases by 286 percent for a 94 percent increase in the total cost of a market hog.

The equilibrium displacement model is specified in terms of percent change so that the absolute levels of impacts are not shown. However, Table 18 provides baseline values of key variables in the simulation model. By multiplying the percent changes determined in the supply and demand model by these baseline values, it’s possible to estimate the actual ending values once pens have been adopted according to the defined scenarios.

Table 19 summarizes the results of the simulations. Producer surplus is the measure of the total net impact of changes on the pork production sector as production decreases and prices increase. The pork producers will lose between $848 million and $4.12 billion due to implementation of group base pen housing. These values are markedly less than the impacts shown in Table 14 which range from $966 million and $8 billion dollars. This is because pork prices are expected to increase, mitigating some of the effects of the increased investment. However, price increases don’t completely compensate for the increased costs because consumers substitute beef, chicken and imported pork which are all now relatively cheaper than pork produced from sows in pens. This is shown by price increases across the meat complex, but pork production decreases and beef and poultry production increases in response to their relatively higher demand. The most likely scenario of capital costs and a two year transition period of productivity losses results in a pork producer loss of $1.5 billion and a consumer loss of nearly $5 billion.

Table 18. Original Values for Key Variables in Simulation.[a]

Variable	Baseline Mean	Coefficient Of Variation (std. Dev./Mean)
Pork		
Farm Pork Price ($/carcass cwt.)	$61.01	17%
Farm Pork Production (million lbs)	19,987	3%
Farm Pork Revenue ($ million)	$12,225	19%
Retail Pork Price (cents/lb)	270.76	3%
Retail Pork Consumption (million lbs)	19,047	2%
Retail Pork Revenue ($ million)	$51,470	5%
Beef		
Farm Beef Price ($/carcass cwt.)	$117.86	11%
Farm Beef Production (million lbs)	25,733	4%
Farm Beef Revenue ($ million)	$30,327	8%
Retail Beef Price (cents/lb)	323.07	11%
Retail Beef Consumption (million lbs)	27,458	1%
Retail Beef Revenue ($ million)	$88,758	12%
Chicken		
Farm Chicken Price ($/carcass cwt.)	$39.11	10%
Farm Chicken Production (million lbs)	44,412	3%
Farm Chicken Revenue ($ million)	$17,390	12%
Retail Chicken Price (cents/lb)	106.74	2%
Retail Chicken Consumption (million lbs)	27,690	6%
Retail Chicken Revenue ($ million)	$29,534	5%

[a]Unless otherwise noted the values are averages of annual values for 2001-2005.
[b]Source: USDA, Economics Research Service, Red Meat Yearbook and Poultry Yearbook. Livestock Marketing Information Center, Retail Prices and Consumption.

At the bottom of Table 19, 'Producer Surplus Neutral Change in WTP" is reported. This shows that to offset the costs of transitioning to pens and to leave producer surplus unchanged, consumers would need to increase their willingness to pay for pork raised in systems with group pen housing by 14 to 72 percent. This value is calculated as the difference the price and quantity demand schedule of consumers to make producer surplus zero and is calculated using only the pork sector of the model. Hence, this represents a conservative estimate of increases in WTP because consumers aren't modeled to sacrifice increased beef and chicken consumption which mitigates the impact of pork increases on consumers. The estimates of willingness to pay from the literature reviewed on consumer response to animal welfare ranged from 18 to 30 percent which lies within the range necessary to compensate producers. However, as described in the literature review on willingness to pay for animal welfare practices, nearly all these values are based on consumers in Europe. In addition, mandated restrictions impose the costs on all consumers, not just those willing to pay a higher value, and a labeling or certification program is more effective at meeting differentiated demands of consumers.

Table 19. Market Level Impacts of Sows Housing Transition From Stalls to Group Housed Pens

		Capital Changes Only		**Productivity Impacts 2 year Transition**	**Capital and Productivity Change**
		18% Net Increase in Pork COP[a]	**35% Net Increase in Pork COP[b]**	**32% Net Increase in Pork COP[c]**	**94% Net Increase in Pork COP[d]**
Variable					
Change in Producer Surplus (Net Impact)					
Pork Producer Surplus	Mill $	-$848.00	-$1,607.49	-$1,491.30	-$4,120.81
Beef Producer Surplus	Mill $	$676.15	$1,318.85	$1,193.20	$3,529.98
Chicken Producer Surplus	Mill $	$267.27	$513.58	$469.23	$1,389.90
Change in Consumer Surplus					
Pork Consumer Surplus	Mill $	-$1,536.93	-$2,977.97	-$2,714.12	-$7,972.88
Beef Consumer Surplus	Mill $	-$963.42	-$1,868.67	-$1,698.46	-$5,068.02
Chicken Consumer Surplus	Mill $	-$323.72	-$632.27	-$576.34	-$1,698.71
Total Consumer Surplus	Mill $	-$2,824.07	-$5,478.91	**-$4,988.92**	-$14,739.61
Change in Farm Prices					
Pork Farm Price	percent	11.04%	5.78%	**19.57%**	57.47%
Beef Farm Price	percent	2.24%	2.08%	**3.94%**	11.56%
Chicken Farm Price	percent	1.52%	2.12%	**2.67%**	7.78%
Change in Retail Prices					
Pork Retail Price	percent	2.98%	5.78%	**5.28%**	15.48%
Beef Retail Price	percent	1.08%	2.08%	**1.88%**	5.53%
Chicken Retail Price	percent	1.09%	2.12%	**1.93%**	5.60%
Change in Total Production					
Pork Production	percent	-2.75%	-5.37%	**-4.92%**	-14.50%
Beef Production	percent	0.33%	0.65%	**0.59%**	1.74%
Chicken Production	percent	0.98%	1.88%	**1.72%**	5.05%
Change in International Trade					
Net Pork Imports	percent	0.74%	1.43%	**1.30%**	3.83%
Net Beef Imports	percent	0.41%	0.79%	**0.73%**	2.11%
Producer Surplus Neutral Change in WTP[e]	percent	14%	27%	**25%**	72%

[a] Existing barns retrofitted to trickle feed small pen housing. Sow productivity identical to stall system.

[b] Existing barns replaced with new trickle feed small pen housing. Sow productivity identical to Stall Housing

[c] Existing barns replaced with new ESF large pen housing. Sow productivity decreases for 2 year transition, then returns to equal to stall systems

[d] Existing barns replaced with new trickle feed small pen housing. Increase in square footage required. Sow Productivity reduced.

[e] Total increase in consumer WTP (total cost) to fully compensate producers for increased cost of production due to transition to pen systems.

Even without producer surplus neutrality, the consumer ultimately pays a large portion of the transition to pens through higher meat prices for pork, beef and chicken. The full simulation shows (Table 19) shows that U.S. consumers will end up paying between $2.8 and $14.7 billion dollars more for all meat products as a result of the conversion to pen based housing.

In addition to the direct impacts on the pork industry, beef and chicken producers gain market share and higher returns due to the changes in the pork industry. This is a result of beef and chickens' relatively lower costs of production and a shift in consumption toward their relatively cheaper meat products. This carries over to international trade, where a combination of greater imports and reduced exports of pork results in a reduction in global competitiveness of the U.S. pork industry.

Summary

Proposals and regulations calling for the elimination of gestation stalls will have dramatic impacts on the pork industry, affecting the foundation of the modern commercial pork production system. This research shows that even absent changes in productivity, any regulations or policies which require conversion of stall facilities prior to the end of the useful life of existing facilities will have potentially high costs, depending on the number and age of facilities in the industry. This point has not been addressed by prior studies which typically make only barn-to-barn comparisons of productivity and ignore the opportunity loss of existing assets with a rapid conversion.

There is well founded concern that there will be productivity differences not yet observed in the limited application of pen housing which exists only in a research context or very limited scale in commercial operations. Respondents to an open ended telephone survey suggested that there were significant learning curves and that the risk of catastrophic problems in pens was greater than in stalls because of the inability to manage sow individually. Still those using pens reported no significant differences in labor, productivity or animal welfare within their own operations

The completed analysis shows that the transition of the pork industry in any case will result in a net economic cost of between $900 million and $4 billion for pork producers depending on the impact on productivity, and additional costs to consumers of between about $3 billion and $15 billion in terms of total meat based protein costs. This would require an increase of between 14 and 72 percent in consumer willingness to pay for pork products produced by sows raised in group pen housing to fully compensate producers for the additional costs.

These quantifications represent reasonable estimates based on current information, but that information is very sketchy – particularly in regard to overall productivity and management concerns. In the next two years, major pork production firms in the U.S. will begin building commercial scale pen facilities. It is highly recommended that the experiences of these systems be carefully documented to determine what the impacts of wider adoption might be. Secondly, as firms consider expansion, it would be very helpful to develop optimal capital replacement models which could help improve decision making and reduce the overall impacts of the transition on the swine industry.

Many issues were not considered which could be addressed, but would make quantitative analysis much more complex and which can be deduced by extension of results already found. With limited data on productivity and management relationships, the model is useful for considering what might happen but following are several factors that could significantly affect the overall impact on the industry which were not modeled.

1. Is there a greater risk associated with quality of management and pen systems?
2. Is group pen housing a better alternative than individual stalls in which pigs can turn around?
3. What is the actual age distribution of the industry's gestation barns?
4. Can barns be transitioned or retrofitted 'on the fly' and what is the lost productivity from the transition?
5. What kinds of genetic changes must be made and what will those costs be?
6. What is the dominant system that promotes sow welfare and minimizes costs? Investment in the wrong system early on could be risky so the producers will be hesitant to adopt the systems until their proven. This is frequently known as 'first mover risk'.
7. How will this transition affect the structure of the industry? Firms with relatively newer investments will be more adversely impacted than firms with an older stock of barns. In addition, this will most dramatically impact sole proprietors who face a human life cycle of business compared to the infinite life of corporations who can also test facilities and afford to learn by doing.

8. What square footage is desired from a sow welfare perspective? If additional square footage is required, this raises issues of additional permitting and siting barns, this may be a challenge and will require allowances for permitting animal units (which theoretically would not change) rather than by construction project.
9. If rapid conversion is necessary, how will this affect the prices of material and construction? With raw material prices such as steel, concrete and lumber already on the rise, increased dramatic demand will likely increase costs over those estimated here.
10. Are there broader effects on farrowing and finishing flows as yet not analyzed? For example, one producer said that management of body condition in farrowing took on much added importance in pen systems.

The numerous alternatives available for sow housing create significant risks. The greatest risk being an issue not addressed in this paper: what is truly meant by sow welfare and what conditions must exist to achieve it? Based on the surveys and previous literature, the net sow welfare differences between stalls and pens are not clear. Sows cannot move in pens, but they are protected from aggressive sows and the inherent biting observed in group housing. In group housing sows can move around, but are subject to aggression. In both cases, sows are still kept in confinement throughout their productive lives. Regardless, transitioning to pens will come at a significant cost. The industry must consider what is meant by sow welfare that is acceptable to the consumer. It may be better to make the correct gestation system change once than to make an expedient change repeatedly. At the same time, expedient policy response has been ‘not stalls’ even though the evidence cuts both ways that the welfare of sows in stalls is not worse than for those in pens. Hence, the policies passed can also be critiqued for requiring a change that may not increase sow welfare, but almost certainly will increase costs to consumers and producers. Failure to do this will place the industry on a welfare treadmill, which will lead to even greater economic losses.

Finally, regulatory mandates are a poor method to improve sow welfare and economic goals. First, as shown it’s not clear what the best alternative system is from a sow welfare perspective. Secondly, mandates impose costs on producers who must implement the systems and ultimately on all consumers, even those who do no share animal welfare concerns regarding current production methods. Alternative instruments that can achieve diverse objectives include the development of effective certification, labeling and marketing programs so that those producers and consumers who share similar views on production methods can efficiently develop those markets for animal welfare attributes.

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Appendix A. Survey Regarding Group House Sow Systems and Raw Responses on Pens

Responses are in italics under the question, they may not match exactly because questions may be addressed under another category. Only producer responses are recorded here. Builders responses are used directly in the simulations and so are provided there. Builders provided capital cost information and transition of facilities that most producers were not able to provide.

Background:

Gestation stalls, defined as housing sows in individual stalls or crates for a majority of their gestation period, are the most widely used method of housing sows in the U.S. Animal welfare concerns have increased calls for alternative systems for sow housing. In other countries such as the UK this has resulted in policies eliminating stalls for gestation periods. In the US, some swine production operations have indicated they will voluntarily phase out stalls over a period of years to accommodate consumer demands.

Prior research on alternative sow housing almost exclusively focuses on the production performance of sows under stall or group pen based housing systems. Almost no research considers the costs of switching from stall gestation housing to pen based group gestation housing. Further, it is likely that implementation of group housing on the scale of a commercial operation will be quite different than in research trials.

The goal of this survey is to gain insight into the cost/benefit trade-offs of implementing group sow housing by questioning producers who have first-hand experience in both systems, often switching from stall housing to group housing, and also questioning industry experts on sow housing.

Respondents are initially sent a copy of the survey to allow them to gather and consider information related to their responses. This will be followed up with an open ended telephone interview using the same survey.

Survey Questions:

I. Brief Description of Sow Housing Status

Note: responses to stall system were standard as expected so for brevity not included.

1. Please describe your traditional **stall** system
   a. Typical number of gestation days in stalls?
   b. Feeding design?
   c. Watering design?
   d. Flooring type?
   e. Number of sows in single barn?
   f. What are the dimensions of the overall barn?
   g. Ventilation in facility?
   h. What are the dimensions of the stall? Is there more than one type?
   i. Feeding practices (once/day, twice per day, etc.)?
   j. Ration formulation (especially fiber content)?
   k. How is breeding done, including boar exposure?

2. Please describe your **group housed pen** system
    a. Gestation period in pens?
        - *First six days in stall for breeding, rest of time in pens*
        - *Gilts in pens up to 3 days before farrowing, in stalls after farrowing ideally 28 days until settled. Prior to 28 days will get 10 percent higher fall-out from pens*
        - *1 week in stalls rest in pens.*
        - *110 days in pens*
        - *In stalls for breeding, rest of gestation in pens*
        - *48-72 hours after breeding, go into pens.*
    b. Feeding design (e.g., ESF, group feeding)?
        - *Floor feeding*
        - *Drop feed on floor*
        - *ESF system*
        - *ESF System*
        - *Floor feeding*
        - *ESF*
    c. Watering design?
        - *Nipple*
        - *Trough, also feed some whey because of availability*
        - *Nipple*
        - *Nipple*
        - *Double nipple*
        - *Bowl*
    d. Flooring type?
        - *2/3 solid 1/3 slat*
        - *Full slats sows, partial slats gilts*
        - *Full slats*
        - *Solid flooring open flush gutter*
        - *60% solid, 40% slats*
        - *Full slat, go to rounded edge to reduce feet and lameness issue.*
    e. Number of sows in single barn?
        - *1,300 in four rooms*
        - *300 sows to 1,000 sows depending on barn.*
        - *350 sows*
        - *600 sows*
        - *2500 sows*
        - *3600*
    f. What are the dimensions of the overall barn?
        - *Varies by barn*
        - *2 barns 121'x301'*

g. Ventilation in facility?
   - *Tunnel*
   - *Fan*
   - *Double curtain, negative pressure ceiling*
   - *Curtain and natural ventilation*
   - *Deep Pit Tunnel*
h. What are the dimensions of the pen?
   - *12' x 14'*
   - *varies by barn*
   - *40'x40'*
   - *41'x28' with 216 breeding stalls, 8-6'x21' recovery pens*
i. How many sows are in a pen?
   - *11 sows*
   - *45-66 sows*
   - *50 sows*
   - *25 with single feeder, 140 with 2 feeders, need less space per sow in larger pens because more opportunity to move around-easier to separate. In small pens the same per sow square footage is not enough.*
   - *6, 10 or 11 sows per pen*
   - *65 sows per pen*
j. How much space is allocated per sow?
   - *15 square feet*
   - *Placed in pen at 15 square feet, after fallouts left with 18 sq ft*
   - *24 square feet per sow*
   - *15 square feet per sow*
   - *15-18 square feet per sow*
   - *17 square foot per sow at start, with fallouts goes to 19.8 square feet*
k. How are sow groups managed? (Note: static means that the same sows are managed as a cohort with no new entrants or exits, in dynamic groups, sows may enter or leave the pen).
   - *Static, sort by parity, one room all gilts, 4 size groups, critical to sort proper*
   - *Static in pens, need about 200 crates for 'parking lot' of 'fallouts' for every 3000 sows in pens. Sort by size and parity, make sure feed before put in pens to reduce aggression*
   - *Dynamic with one entry of sows 2 weeks after the pen is first loaded.*
   - *Weaned an penned according to size and condition, managed by group until 30 days pregnant then moved into larger group. Always managed together.*
   - *Static, no mixing in pen but will mix coming out of farrowing.*
   - *Static groups with 10-15% fallouts for culls, lameness and death loss and 1-2% of gilts will never train into ESF.*

l. Feeding practices (once/day, twice per day, etc.)
- *No differences*
- *Dry feed 2x per day, ½ diet per feeding to give two opportunities*
- *Once per day, no difference*
- *Ad lib with ESF, but controlled by entries, and fed by condition score, parity and length of gestation with 4-5 condition scores.*
- *Once per day*

m. Ration formulation differences?
- *No differences*
- *No differences*
- *No differences*
- *Gilts different than sows but lot of minor variations not significant*
- *No difference*
- *No difference considering adding more fiber*

n. How is breeding done, including boar exposure?
- *Breeding in stalls*
- *Breeding in stalls*
- *Breeding in stalls*
- *Breeding in pens*
- *Breed in stalls*

o. How is preg checking done and how frequently?
- *Done in pen 2x*
- *Done in stall @ 4 weeks*
- *Done in pen no problem*
- *@ 30 days only once*
- *Done in pens, easy with small pens, can reach sows.*

II. Production Performance Impacts.

1. What is the impact on the key production performance parameters (percentage change <u>or</u> absolute differences)?

a. Farrowing rate?
- *3% lower in pens*
- *1% lower in pens but not significant difference*
- *2% lower in pens*
- *75-85%, much lower than stalls, too much interaction in first 30 days, need to keep stalled for 30 days*
- *Low farrowing rate 70% for pens not sure cause.*
- *78% to 79.2 percent, about 5% lower*

b. Piglets born live per litter?
- *¾ of pig lower in pens*
- *.6 pigs higher pens*
- *no difference*
- *slightly lower*
- *12.5 about 7% higher*

c. Stillborn pigs per litter?
   - *4% pens, system wide 5.5%*
   - *1.1 in stalls and .6 in pens*
   - *1% lower in pens*
   - *half the rate of stall facilities*
   - *very few stillborns*

d. Total pigs born per litter?
   - *No difference*
   - *12.5 stalls and 12.7 pens*
   - *No difference*
   - *9.8 to 10 compared to 10.5 for stalls*
   - *9.5 to 9.8*
   - *about 8% higher*

e. Piglet birth weight?
   - *No difference*
   - *No difference*
   - *No difference*
   - *No difference*
   - *No difference*

f. % of females bred that are gilts?
   - *No difference*
   - *No difference*
   - *Replacement rate higher in pens by 5%*
   - *45% culling rate so about same*
   - *No difference*
   - *Much higher, 44% but still in start-up phase of multiplier*

g. Average days open (wean to breed)?
   - *No difference*
   - *Stalls 8.6, pens 7.3*
   - *Higher at about 10*
   - *No difference*

h. Feed consumed?
   - *15% loss due to floor feeding*
   - *no difference*
   - *no difference*
   - *No difference*
   - *No difference*

i. Frequency of abortions?
   - *No difference*
   - *Had PRRS break so hard to say*
   - *No difference – is PRRS easier to control in pens, may be*
   - *No difference.*
   - *No difference*

2. What have been impacts directly on sow health and behavior (specify percentage change or absolute differences)
    a. Death loss?
        - *8% pen, 7.5% system wide*
        - *10% pen, 11.6% stalls*
        - *1% higher in pens*
        - *very low death loss 1.5%*
        - *6.5-7% death loss in pens.*
        - *133% higher death loss during start-up phase, had trouble getting condition to be right. Gradually straightened it out by adding more sows to pen and really managing sows coming out of farrowing to be in good condition, and better sorting.*
    b. Lameness or sore feet?
        - *4% higher in pens*
        - *10% more leg issues in pens*
        - *Much more in pens, fighting plus catch feet in slats.*
        - *This resulted in closing operation, 35% of sows had at least one sore foot, due to flooring system rather than pens per se, also real problem at first entrance, should probably wean into crate rather than into pen.*
    c. Lesions and scrapes?
        - *Higher in pens from sows fighting, 100% first 5 days as adjust.*
        - *80% more lesions on sows in pens*
        - *10x lesions in pens, more fighting*
        - *Not many more lesions*
        - *Usually in first few days of penning most have lesions.*
    d. Injuries due to biting?
        - *20-25% vulva biting last two weeks prior to farrowing*
        - *Most due to vulva biting at beginning and mid way through, not so much at end 2 weeks.*
        - *Vulva biting in pens.*
        - *Significant problem with vulva biting if leave in pen after day 110 of gestation.*
    e. Body condition?
        - *50-75 pounds heavier in pens, just seem to get heavier, really have to watch. Also greater variation from sow to sow.*
        - *10% more thin sows in pens most go to parking lot*
        - *About the same, but took time with ESF*
        - *Needed to adjust fast, could get very heavy sows, and need to monitor body condition closely.*
        - *Body condition issues in ESF resulted in very high death loss in start-up need to manage this.*

f. Longevity in herd, number of parities?
   - *No Difference*
   - *No difference*
   - *Higher culling rate and lower parity on average with pens may affect productivity*
   - *Culling necessary due to lameness problem otherwise probably the same.*
   - *Lower longevity due mostly to farrowing rate.*

g. Stereotypic behavior ('bar biting, ONF)?
   - *Not noticeable*
   - *Not noticeable*
   - *Some behavioral problems around feeders, aggressive sows trying to sneak in 'sharp's' always looking for feed.*
   - *See some more in stalls, but may be due to feeder design because if they rattle the feeder a little bit of feed drops out.*
   -

h. Other?
   - *Sows became incredibly tame, could walk through pen no problem.*

III. Management and Stockmanship

1. These questions relate to the overall management and stockmanship related to stall versus group housed pen facilities.
   a. What is the overall labor difference between stall and group housing? (Labor includes daily activities such as feeding, cleaning pens, checking health, moving sows, breeding, boar exposure, etc.)
      - *No Difference*
      - *Takes more time to run returns in pens v stalls, sometimes hard to move out of pens.*
      - *10-15% increase in labor with additional training. Moving parts of ESF creates more maintenance time, sows can be hard to 'find'.*
      - *Total labor was about the same but different. More health time, less feeding and cleaning.*
      - *No difference over all, but some different activities*
      - *Labor about equal, maybe a little less*

   b. Is there a difference in the number of workers required?
      - *No Difference*
      - *No difference*
      - *No more workers but a bit more time.*
      - *No more workers, just different activities*
      - *About the same*

c. What is the overall management difference between stall and group housing? (Management includes overarching activities such as diet formulation, managing breeding and gestation schedules, managing sow flows/grouping, etc.)
   - *Must be better management – hard to quantify*
   - *Making sure sows get moved at right time is difficult, but easier to walk pens, need to be able to pick out sows in pens better, but probably a wash.*
   - *Additional management of ESF to make sure it works.*
   - *Need a little better herd skills, especially moving sows into big pens, need to learn dynamics of behavior, need to manage flows and grouping. Also ESF helped with management because daily printout of sows lets you know who's off feed, etc. But big problem is keeping ESF working properly.*
   - *No difference in total management, but need to be able to manage uniformity better and watch condition scores*
   - *Very steep learning curve and training is important in ESF technology.*

d. Have you changed any practices or procedures to accommodate group housing and how much have they impacted your costs?
   i. Breeding schedules?
      - *No Difference, but must have 40 days in crate after breeding.*
      - *No difference*
      - *No differences*
      - *No differences*
      - *No differences*
      - *No difference*

   ii. Preg Checking?
      - *No difference*
      - *No difference*
      - *No difference*
      - *No difference*
      - *No difference*
      - *No difference*

   iii. Health management?
      - *No difference, but must allow additional crates for pull-outs, no where to go with them.*
      - *Need hospital crates or parking lot*
      - *No difference.*
      - *Issue with sore feet, but not due to pens per se*
      - *Should have added more stalls to use as hospital stalls, so need to have stalls through gestation.*

   iv. Estrus detection?
      - *No difference*
      - *No difference*
      - *No difference*

v. Additional sow movements/handling?
  - *No difference*
  - *One more sow movement with pens from breed stall to pen.*
  - *More movement and dynamics because move from small groups to large group, but this is not necessarily common method.*

vi. Increased observation?
  - *No difference*
  - *Need to be able to pick out sows from group in large pens.*
  - *No difference*
  - *No difference*
  - *No difference*

e. Have you made any adjustments to genetics? If so, can you provide an estimate of the costs of this adjustment?
  - *No difference*
  - *No difference*
  - *No changes*
  - *Did not change, but probably needs to be addressed, mostly attitude related but how to get docile sows and high performing pigs?*
  - *Landrace/Duroc cross, have not made changes.*

f. Are there any other management changes which have had to be made in farrowing or subsequent stages?
  - *No difference*
  - *Need to worm in farrowing crates used to do it in stalls, sows behave about the same in farrowing.*
  - *No difference*

g. Has any retraining of employees been necessary, what are the estimated costs of retraining?
  - *All got re-training, approximately 2 weeks*
  - *Minimum of 1 year transition will lose some productivity but then back to comparable to stalls.*
  - *Biggest learning curve is moving sows at right time, but no difference really.*
  - *Need additional 4-5 days to understand computer system.*
  - *Need a bit more training on ESF and group management but not a huge issue*
  -

h. Have injury rates or other worker health issues changed what are the costs of these changes?
  - *No Difference*
  - *No difference, but should have 2 people around when enter pens.*
  - *There is the opportunity for higher injury rates mingling with sows but didn't see it.*
  - *Workers like working in ESF facility better than stalls, less noise and less dust.*

IV. Facility Design and Costs

Previous questions addressed barn level issues. However, if gestation pens are implemented due to regulations, it will be necessary to transition the industry from its existing facilities to group housed pen facilities. The following questions address two scenarios: retrofitting existing facilities or building new facilities. Each has a different set of implications on industry impacts.

1. The following questions pertain to **retrofitting** existing stall facilities into group housed and pen based facilities. Retrofitting means that a stall barn is converted based on the same overall footprint of the facility.
    a. What was the cost of converting a stall barn to a group housed facility (per sow basis and as total)?
    b. What was required to complete the retrofit (changes made to flooring, ventilation, feeding systems, etc.)?
    c. Does the retrofitted barn have the same capacity and utilization rate as the stall facility? How much does it differ (# sows, etc.)?
    d. Will retrofitting facilities require the addition of new facilities to compensate for any reductions in capacity if any from question (c)?
    e. Was there down time related to the retrofit and what was the cost of lost productivity due to the transition?
    f. How long did it take to retrofit the facility?
    g. How long do you think it would take to retrofit all your facilities?
    h. Have there been additional costs related to the group housed system and what are the differences in costs?
        i. Facilities Maintenance Costs?
        ii. Waste Management Costs?
        iii. Utilities Costs?
        iv. Others?
2. These questions are regarding implementation of **new** group housed facilities over time.
    a. What is the comparable cost of a new group housed facility compared to existing stall facilities (percent difference)?
        - *ESF could require additional square footage 15-20%*
    b. What is the average age of your existing stall facilities?
        - *10, 15 and 20 years old*
        - *10 to 25 years old*
        - *6 years old*
    c. What is the expected remaining life of your existing stall facilities?
        - *15 to 20 more years*
        - *about 10-15 years*
        - *20 years*
    d. If you replaced stall with new group housed facilities, how long do you believe it would take to completely transition to group housed facilities if you did it according to normal replacement rates?
        - *Would need at least 10 years. 110,000 sows in system if had to change in five years could simply not do it, would have massive productivity decline.*

- *Need at least 2 years to convert completely, but retrofitting depends heavily on the existing flooring type.*
- *Would need about 10 years, about time equipment needs replaced.*
- *Might be able to retrofit gestation as rotate sows into farrowing, but haven't tried it directly.*

i. Have there been additional costs related to the group housed system and what are the differences in costs?
   i. Facilities Maintenance Costs?
   ii. Waste Management Costs?
   iii. Utilities Costs?
   iv. Others?

V. Overall Assessment

1. Overall, provide a **high, low and most likely** estimate of the cost impacts (on a percentage basis) of switching from stalls to pens for gestation?
   i. Based on your overall experience, what is the total expected cost differential you would estimate from switching from stalls to group house pens in your operations?
      - *About 50-75 cents/weaned pig in capital and about $20/sow increase in costs with pen.*
      - *All dictated by square footage, less penning, less heating because lay together, less insulation so maybe a wash with no change in square footage.*
   ii. How much would you expect this overall cost to increase or decrease if you were to replicate this system to include all of your production operations? (In economic terms, do you expect there to be economies of scale to the transition)?
   iii. Please provide an overall estimate of the time that would be required for you to transition all of your gestation operation to group housed facilities?
      - *Could transition in about 6 months minimum, but many issues would be ongoing.*
      - *If go from stall to pens will have similar productivity. However, potential for huge nightmare with pens. Potential risk increases with mismanagement if don't understand dynamics. So, transition risk during learning period is huge.*

Are there any other factors which are not addressed in this survey which you believe are important to the implementation of potential sow housing alternatives and the development of industry guidelines, policies or regulations?

- *May need genetic changes depending on square footage requirements.*
- *Must be able to at least put sick animal in crate and 40 days post breeding. Difficult to completely eliminate stalls for those purposes.*
- *Consider the impact in England – 40% reduction in sow herd from rapid transition.*
- *Biggest cost is asset turnover, time to design and retrain people, transition will be costly, must allow 30 days in crates post breeding.*
- *Variation from barn to barn of pen facilities is much greater than variation from barn to barn in stall facilities – believed to be due to group dynamics just like people.*

- *Key issue is what is the square footage required by sow. If need to increase footprint of facilities will have real trouble getting them permitted and this will add costs.*
- *Cannot convert until worn out, otherwise will incur large capital costs.*
- *Overall costs of production would again implement pen ESF system, but first six months was very difficult. Took at least six months to get big problems worked out, now at 18 months is performing well. Would like to try groups up to 120 sows. Issue with ESF is that can use same square footage as with stalls, with trickle or free stall would need to add so much square footage that concrete becomes more expensive. Could retrofit stalls into ESF on same square footage.*

Appendix B: General Schematics of Gestation Housing

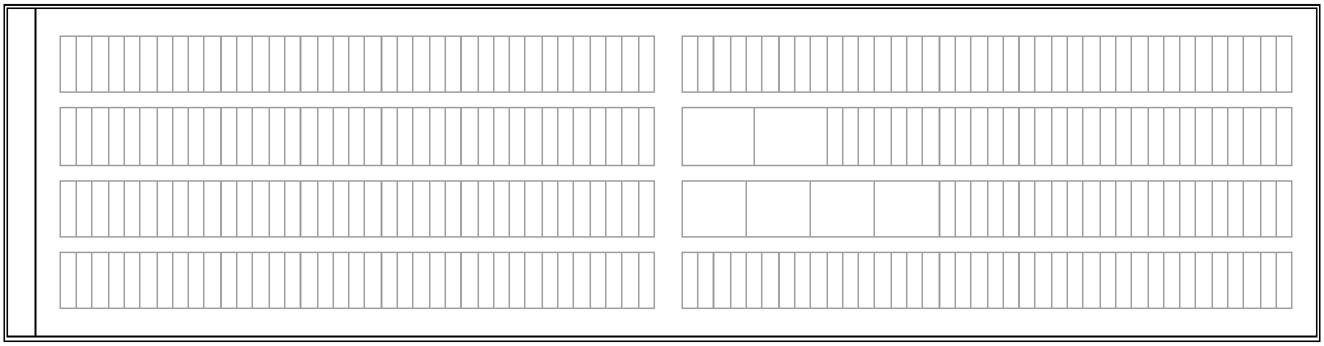

Figure B.1. Prototypical Gestation Stall Barn, Stalls 7’ x 2’. Aisles 4 feet.

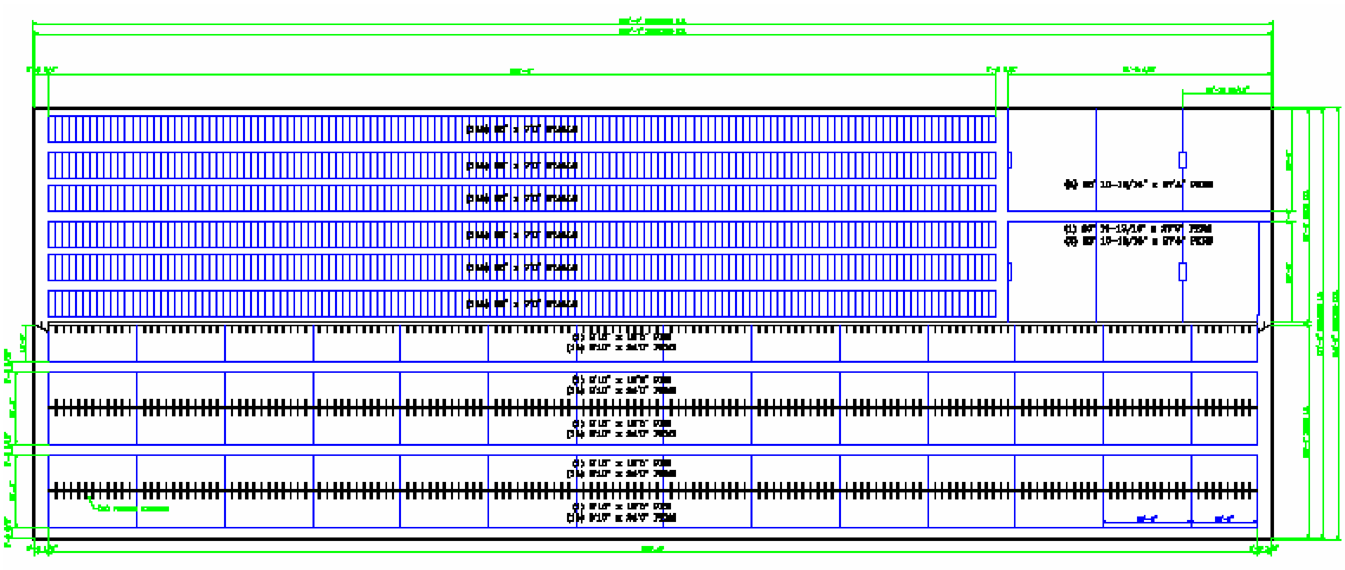

Figure B. 2. Small Pen Trickle Feed Housing. Stalls included for breeding and settling sows as well as parking fall-outs from pens.

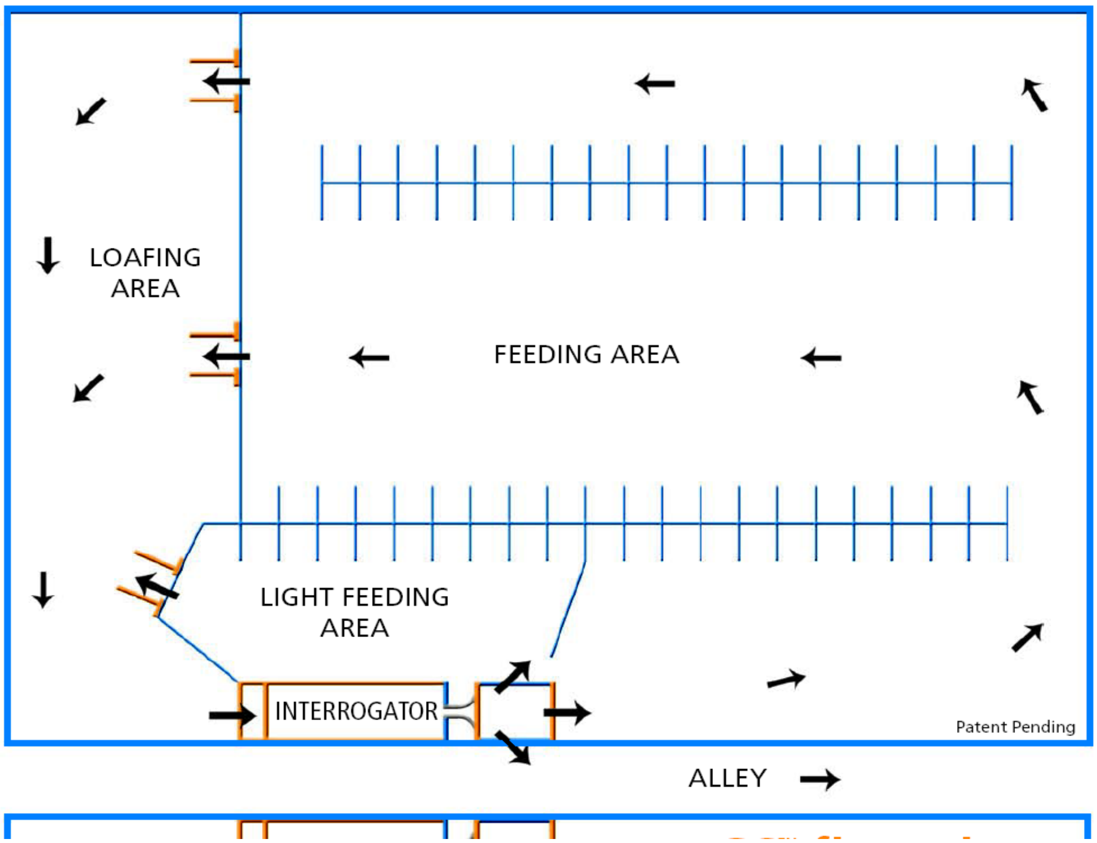

Figure B.3. Large Pen Floor Feeding with Electronic Sorting to Manage Feed.

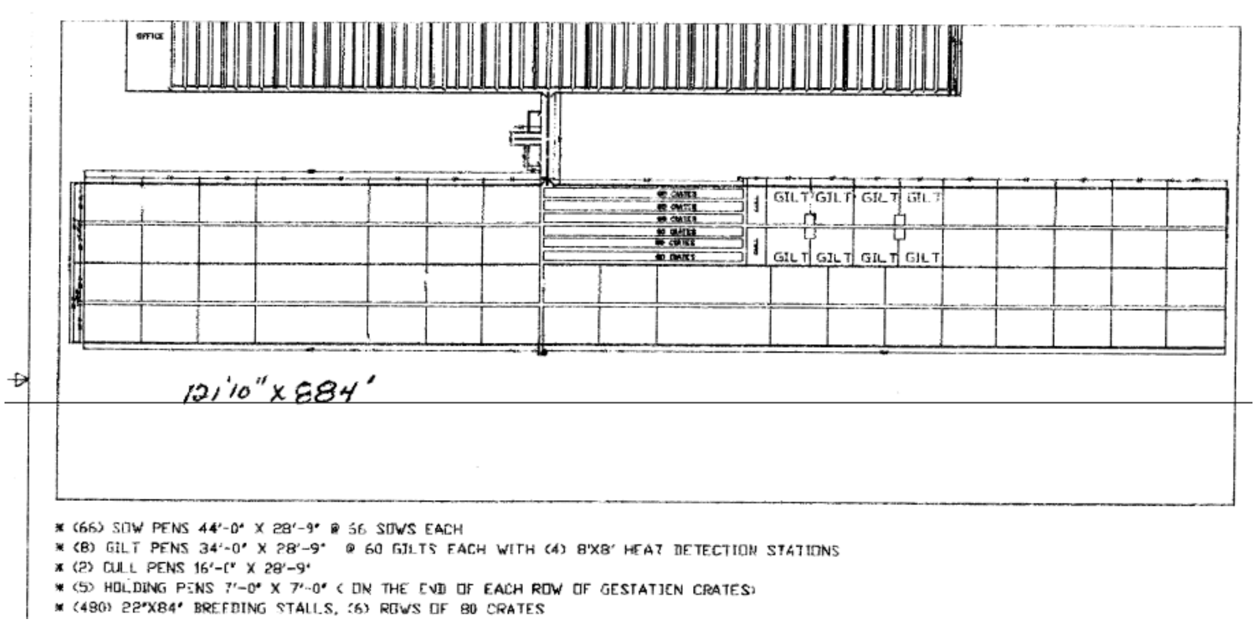

Figure B.4. Large Pen (66 sows) ESF Design, Includes Breeding Stalls.