Optimizing Energy Use in Pig Production: An Examination of Iowa Systems

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Summary and Implications

Energy is used in all aspects of pig production, from the manufacture of materials used in building construction to the cultivation and processing of feedstuffs. Historically the availability of fossil fuels has minimized pressure to consider all uses of energy in pig production. Rising energy prices, uncertain access to petroleum supplies, and recognition of the environmental impacts of fossil fuels are increasing awareness and incentive to reduce consumption of limited resources. This project estimates non-solar energy use for pig production options in Iowa.

The baseline system produces 15,600 pigs annually using confinement facilities and a corn-soybean cropping sequence. Diet formulations for the baseline system include supplemented synthetic amino acid L-lysine and exogenous phytase. The baseline system represents the majority of current pork production systems in Iowa and the Upper Midwest where most U.S. swine are produced. This system is designed to minimize land-surface area requirements and encourage maximal pork production per unit of feed net energy and standardized ileal digestible lysine fed to pigs. The baseline system for swine production in Iowa is estimated to require 5.5 MJ non-solar energy/kg of live weight pig produced. In general producing pigs in Iowa in 2009 requires about 85% less non-renewable energy compared to 1975.

An alternative system using hoop barns for grow-finish pigs and gestating sows was also evaluated. Using bedded hoop barns for gestating sows and grow finish pigs requires less energy to heat and ventilate buildings, but more energy to grow and process feed than conventional systems. Using hoop barns for swine production requires more feed and thus more non-solar energy to grow and process feed ingredients. However the savings in non-solar energy associated with operating hoop barn-based swine systems relative to conventional confinement systems nearly offsets those inputs. The alternative hoop-based system would require 5.6 MJ non-solar energy/kg live weight.

The total energy used for both housing systems is very similar. Energy use for pig production is influenced by crop sequence and diet strategy with nitrogen management being a critical leverage point.

Introduction

United States pig production is concentrated in Iowa, and is a major influence on the economic and ecological well-being of that community. Although often viewed as isolated entities at a macro-level, production of both crops and livestock are heavily influenced by each other. Recognizing influences between crops and livestock, and particularly utilizing complementary aspects of pig production and cropping systems is essential for achievement of greater sustainability.

A pig production system consists of three features: the buildings used to house pigs, the diets fed the animals, and the cropland used to produce the feedstuffs. Energy is used in all aspects of pig production, from the manufacture of materials used in building construction to the cultivation and processing of feedstuffs. Historically the availability of fossil fuels has minimized pressure to critically consider all uses of energy in pig production systems. Interest in non-solar energy use for all sectors of society is increasing due to rising energy prices, uncertainty about access to fossil fuel reserves, and growing consensus about the deleterious implications fossil fuel use has for global climate. Comprehensive, accurate information is critical to informed decision making. However analysis of energy use by modern pig production systems in Iowa, the region, and United States is lacking.

Materials and Methods

Process analysis methodology was used to calculate direct and indirect energy inputs into and through pig production systems based on physical material flows. Similar to contemporary European assessments, a cradle-to-gate approach of life cycle assessment that included embodied energy one step before the farm was used. Life cycle assessment (LCA) is a technique used to quantify and compare environmental impacts of products or processes. Although most commonly applied to manufacturing processes, LCA is increasingly being applied to agriculture. Consistent with process analysis methods, we did not include solar energy and human labor inputs. Managing pigs in hoop barns requires a different set of skills and proficiencies compared to managing pigs in conventional systems but labor is generally assumed to be similar for both types of housing systems.

Energy is categorized as embodied or operating based on how they are used. Embodied energy refers to the quantity of energy required to manufacture, provide, or supply a product, material, or service. In pig production, energy used to produce facility components such as concrete, steel, plastics, and lumber are examples of embodied energy. Operating energy is the energy required for a system to function on a daily basis—electricity for ventilation systems and energy in feed consumed by pigs for example. Three non-solar energy sources were considered: diesel fuel, liquefied petroleum gas, and electricity.

Simplified design models of buildings used for each stage of pig production were generated and used to estimate building material use. Modeled building dimensions, layout, and material choices were determined based on interviews with construction firms, facility managers, and industry consultants. Five primary building materials were estimated: concrete, steel, lumber, insulation, and thermoplastics. The mass of each type of building materials used was then multiplied with reference values for construction materials to calculate the embodied energy of materials present in a newly constructed pig facility complex. Energy use for site preparation was estimated based on construction estimating references.

Energy use for one 365-day period was modeled for each phase of pig production. The analysis includes energy used for thermal environment control (heating and ventilation), pumping water, cleaning facilities, and providing illumination, as well as feed consumption and bedding use as appropriate. Historic hourly temperature data for North Central Iowa was combined with pig flow assumptions to model energy use for heating and ventilating each type of pig facility.

A crop production model for Iowa was developed and used to evaluate three types of non-solar energy inputs: diesel fuel, liquefied petroleum gas, and electricity. The energy used to produce key crop-production inputs that would be produced only if crop production occurred—seed, fertilizers, and pesticides for example—were also estimated. The non-solar energy use associated with producing and delivering 13 swine feed ingredients in Iowa was calculated and summarized.

A final summary analysis was performed that considered different combinations of facility type, crop sequence, and diet formulation strategy. This analysis considered nutrient excretion from pigs based on diet formulation. It also considered nutrient delivery to cropland by various forms of pig manure (liquid slurry from conventional confinement or composted solid from hoop barns) and displaced synthetic fertilizers. The non-solar energy use by each component of the pig production system are summarized for selected scenarios and reported.

Results and Discussion

Table 1 presents the non-solar energy associated with farrow-to-finish pig production using different housings systems in Iowa. The conventional system assumes facilities are mechanically ventilated with liquid manure handling systems. It was assumed that these buildings have a 15-year useful life span. Pigs are fed a corn-soybean meal diet that includes synthetic amino acids and exogenous phytase. Producing one - 300 lb market pig from this system requires 744 MJ of non-solar energy. More than 60% of this energy use is accounted for by cultivated crops and processing feed. About 25% of the non-solar energy associated with producing the typical market pig in Iowa is used to operate facilities.

The hoop-barn based alternative uses bedded hoop barns for grow finish pigs and for gestating sows. Conventional facilities are used for farrowing and nursery pigs. Pigs in this system are also fed a corn-soybean meal diet that includes synthetic amino acids and exogenous phytase. Producing one - 300 lb market pig from this system requires 768 MJ of non-solar energy. About 75% of energy use is attributed to cultivating crops and processing feed. Cultivating crops for the hoop barn-based system requires 30% more energy than cultivating crops in the conventional system. There are two reasons for this, first it was assumed that pigs housed in hoop barns consume more feed than pigs in conventional systems. Secondly, liquid pig manure from conventional facilities and swine manure compost from hoop barns have different nutrient content and release rates. In the conventional system, applying pig manure to cropland allows the removal of more synthetic nitrogen fertilizer than in the hoop barn-based system.

Conventional facilities require nearly 40% more non-solar energy to operate than hoop barn-based systems. Conventional systems rely on fans and heaters to regulate the thermal environment. These technologies allow tight control of thermal conditions, but require energy to operate. Alternatively, pigs in hoop barns are provided bedding year round and consume more feed during cold periods of the year. Despite these production system differences the total non-solar energy use for pig production in Iowa is similar for the two systems.

Table 2 presents the published literature values for non-solar energy use associated with pig production. The last comprehensive analysis of energy used in Iowa pig production was completed during the late 1970's. At that time producing pork in Iowa required 16.4 MJ non-solar energy/lb with 72% of the energy use being attributed to feed production and processing. Over the last 34-year period (1975–2009) the energy cost of producing pork in Iowa has decreased by 85%.

Modern European pig production systems rely on imported feedstuffs, particularly soybean meal, thus pig production in Europe requires 3–8 times more energy than producing pigs in Iowa. The reported value for Denmark in 2005 (2.9 MJ/lb liveweight) is similar to Iowa in 2009 (2.5 MJ/lb liveweight) however that project only considered energy to cultivate and process feedstuffs. The study also did not include the energy use for maintaining sow herds and developing the pigs from weaning to feeder pig size. In general 60-70% of the non-solar energy use associated with producing pigs results from growing and processing feed. Because of this it is understandable how a "feed-only" focus has developed in terms of energy use in pig production. However given that 25% of the energy use of a modern pig production system results from operating the housing facility it is clear that future strategies to optimize energy use in pig production systems cannot ignore this factor.

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Table 1. Non-solar energy associated with farrow-to-finish pig production in Iowa under different housing scenarios[1].

	Conventional MJ/300 lb market pig	Hoop Barn-based MJ/300 lb market pig
Facility construction	87.0	73.2
Facility operation	185.4	113.9
Cultivation of crops	354.1	464.3
Processing of feed	102.4	105.5
Manure application	15.1	11.1
Total	744.0	768.0

[1] Conventional = mechanically ventilated facilities with liquid manure handling systems for all phases of production
Hoop-barn Based = mechanically ventilated facilities with liquid manure handling systems for farrowing and nursery phase; bedded hoop barns for finishing; bedded hoop barns with individual feeding stalls for gestation.

Table 2. Summary of published energy assessments of pig production.

Location	Production Year	Non-solar energy input, MJ/lb live wt.	Non-solar energy attributed to feed, % of total
Iowa	1975	16.4	72.2
United States	1975	16.9	71.7
Sweden	1993	21.0	61.0
Belgium	1998	6.6	73.0
France	2005	7.2	74.0
Denmark[a]	2005	2.9	100.0
Iowa: Current study			
Conventional	2009	2.5	61.4
Hoop Barn-based	2009	2.6	74.2

[a] Only examined grow-finish phase and focused exclusively on feed production and processing.