# Life cycle assessment of two Australian pork supply chains

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**ABSTRACT**

Australia's primary industries are under increasing environmental, social and economic pressure to measure and reduce resource use and environmental impacts. For the pork industry, major resource and environmental issues are related to water use, energy use (primary energy – PE) and greenhouse gas emissions (measured as global warming potential – GWP). To address this, a project was conducted to assess of water use, PE, and GWP of two Australian pork supply chains using life cycle assessment. One supply chain was located in southern Australia with pigs grown-out in deep-litter sheds. The second supply chain was located in northern Australia, where all pigs were housed in slatted and flushed sheds. The study investigated pork production through to the point of wholesale distribution of carcasses using the functional unit, '1 kilogram of hot standard carcass weight – HSCW'. Primary energy use in the two supply chains varied from 20.3 – 24.5 MJ/kg HSCW and GWP for the two supply chains measured 3.1 and 5.5 kg $CO_2$-eq./kg HSCW. Waste stream emissions were found to be the major contributor to GWP.

*Keywords*: pigs, pork, energy, GHG, Australia.

## 1. Introduction

Australia's primary industries are under increasing environmental, social and economic pressure to measure and reduce resource use and environmental impacts. For the pork industry, major resource and environmental issues are related to water use, energy use and greenhouse gas (GHG) emissions, however, to date there has been no assessment of resource use or GHG emissions from the whole Australian pork supply chain. This paper presents results for global warming potential (GWP) and primary energy (PE) use from two Australian pork supply chains (water results are presented in Wiedemann *et al.* (2010) and Wiedemann and McGahan. (2010)).

A great many resources are used in the production of pork at many different points in the supply chain, however the greatest intensity of resource use is generally required for on-farm production of the pigs. GHG emissions occur from a range of sources including the burning of fossil fuels (coal for electricity generation, liquid fuels, gas) and from livestock related emissions (i.e. methane and nitrous oxide from piggery waste streams). Several LCA studies have been done for various types of management systems of pork production, primarily in Europe (Basset-Mens and van der Werf, 2005, Cederberg and Darelius, 2001 cited in Cederberg and Flysjo (2004), Cederberg and Flysjo, 2004, Dalgaard *et al.*, 2007, Weidema *et al.*, 2008, Williams *et al.*, 2006). The most common impact categories assessed were global warming potential (GWP) and primary energy (PE).

A study was conducted was conducted to primarily provide information to industry on the environmental impacts of producing pork in Australia. Other goals included identifying and validating environmental research priorities in the pork production supply chain and to inform industry and government research investment; identifying the environmental impacts of different production systems (i.e. deep litter compared to conventional production sys-

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tems); and identifying the likely environmental impacts associated with changing waste stream management (particularly the environmental benefit associated with capturing methane from the liquid effluent treatment ponds).

## 2. Materials and Methods

The system boundary was established to include the primary production system (pig farms), extending to the meat processing plant docking gate (point of distribution). The functional unit of the study was 1 kg of hot standard carcass weight (HSCW) pork at the meat processing docking gate, represented as whole carcasses, not retail-ready products. The modelling considered the impacts of a 'static' production system for a determined timeframe (2007/08).

### 2.1 Supply Chain Description

The assessment compared alternate management systems and geographical regions to provide an indication of variability of environmental performance within the Australian pig industry. Two pork supply chains were investigated as part of the study. They are referred to as the northern (Queensland) and southern (Victorian) supply chains.

The northern pork supply chain consisted of a conventional farrow-to-finish operation, with feed supplied by two off-site feed mills and sale pigs marketed to several meat processing plants. The piggery is a closed production system, with all pigs bred on-farm. This piggery had three distinct production units on the one farm; a multiplier facility, a breeding facility and a finishing facility.

The southern supply chain piggery consisted of a conventional farrowing unit producing weaners (3 weeks of age), followed by deep litter grow out units (where pigs are housed on litter rather than slatted floors) that house pigs through to sale. Feed for each enterprise was supplied from an off-site feed mill owned by the pig breeding company. Sale pigs were marketed through a single meat processing plant. Pigs were reared to weaning age (3 weeks) in conventional concrete slatted floor housing where effluent is flushed into a liquid effluent treatment system. From the breeder system, the weaned piglets are transported to a deep litter weaner facility where they are housed until 8 weeks of age. From this facility they are transported 240 km to a deep litter grow-out facility, where they are housed until finishing weight (95 kg). From there they are transported 175 km to the meat processing plant.

Both case study supply chains are large, progressive piggeries that operate using the best management practices for Australian pork production with peak performance.

### 2.2 Data Collection

Foreground data were collected from all farms in the supply chain for a period of one year (2007/08). This included farm infrastructure and machinery associated with the piggery operations, but not the meat processing plant. Foreground data were also collected for feed milling and diet formulation as an input to the modelling of production and upstream impacts from feed supply. Data for feed grains were modelled using a desktop assessment based on literature and local expert knowledge of Australian grain production. Foreground data were collected from four meat processing plants where pigs were slaughtered. The processing plant data were aggregated to highlight differences in the pig farms rather than the processing plants.

### 2.3 Modelling the Supply Chain

Greenhouse gases from agricultural systems arise from complex waste stream and soil processes and are emitted from several points on a pig farm (the piggery shed, effluent treatment pond and soils). Emissions were calculated by conducting a mass balance of the piggery system using the program PIGBAL (Casey *et al.*, 2000), which recommended as the Australian tier 2 approach (DCC, 2007). The mass balance was focused on carbon and nitrogen, and considered production inputs to the piggery (primarily feed) and production outputs (sale pigs, mortalities). These production inputs and output were based on foreground data collected from the piggery, and were cross checked against waste stream parameters. The mass balance program estimated excreted carbon (in the form of undigested feed and volatile solids in manure) and nitrogen. Emission estimates used methods and factors from the Australian tier 2 methodology for GHG assessment (DCC, 2007), which is based on the IPCC (2006). For methane estimation from lagoons, the DCC (2007) recommends a Bo factor of 0.45 $m^3$ $CH_4$/kg VS (as recommended by the IPCC for Oceania) and an MCF of 90% (which is 10% higher than the highest values recommended by the IPCC for lagoon systems). Nitrous oxide factors for Australian systems are considerably lower for direct soil emissions under dryland crops than are observed in European countries (EF = 0.03%), while indirect emissions from ammonia volatilisation are similar (EF = 1%). At the piggery, nitrous oxide from deep litter systems were higher (EF = 2%) than recommended by the IPCC (2006). Emissions from effluent and manure application used an EF of 2%. Simapro™ was as used for the impact assessment.

Allocation of co-products was done using a mass allocation process without differentiation between prime pigs, cull pigs or edible offal.

## 3. Results

Primary energy use in the two supply chains varied from 20.3 to 24.5 MJ/kg HSCW (southern and northern supply chains respectively). Primary energy use was lower for the southern supply chain (deep litter housing for weaner/finisher pigs) which was partly in response to lower energy demand for pig housing.

Global warming potential for the two supply chains were 3.1 – 5.5 kg $CO_2$-e / kg HSCW for the southern and northern supply chains respectively. The contribution analysis showed that waste stream emissions of methane ($CH_4$) was the single largest contributor to supply chain GWP, particularly for the northern piggery which utilised a liquid effluent treatment pond system.

To improve the comparability of the results with studies presented in the literature, allocation at the point of slaughter between primary products and co-products was also done using the three most common methods (Table 1). System expansion using an alternative product as the marginal substitute for edible by-products (offal) and low grade pork from cull sows was also done for comparison. This used grass-fed Australian beef. Beef is used in many Australian processed meats as a blend with pork, which was seen as a justification for considering this product a valid substitution. Emissions for grass-fed beef were estimated following the Australian tier 2 methodology and resulted in similar values to those reported in previous Australian beef studies (i.e. Peters et al. 2010).

**Table 1:** GWP for pork production with three methods for allocating emissions to co-products

| Supply Chain | Units | Mass allocation | Economic allocation | System Expansion (grass-fed beef) |
|---|---|---|---|---|
| Northern Supply Chain | kg $CO_2$-e / kg HSCW | 5.5 | 5.6 | 5.0 |
| Southern Supply Chain | kg $CO_2$-e / kg HSCW | 3.1 | 3.6 | 2.3 |

A series of sensitivity tests and scenarios were conducted to test these data and compare with a modified system (pond covering and methane flaring). These are reported in the discussion section. A sensitivity analysis of emission factors for methane production per unit of volatile solids produced in manure and nitrous oxide per unit of nitrogen produced in manure or utilised in land application of waste showed a cumulative range from -28% to + 59% for GWP in the southern supply chain, and -29% to + 11% for the northern supply chain depending on the emission factors applied.

## 4. Discussion and Interpretation

Primary energy in pork production in the literature ranged between 15-18 MJ/kg carcass weight (CW), though one study (Weidema *et al.*, 2008) was an order of magnitude higher than this at 193 MJ/kg CW. Primary energy use for the Australian production systems (20.3 to 24.5 MJ/kg HSCW) was 10-54% higher than most studies presented in the literature. This is likely to be in response to a greater GHG footprint of electricity supply and greater transport distances in the Australian pork supply chains.

On the basis of GWP, results from the two Australian supply chains were comparable to other studies presented in the literature (see Table 2). For the southern system, where pigs are raised on deep litter from 3-23 weeks, the GWP was comparable to the lowest emissions reported in the literature (Table 2).

**Table 2:** GWP from Australian and international pork production studies reported in the literature

| Reference | Country | GWP kg $CO_2$-e/kg CW[1] | Main contribution to burden |
|---|---|---|---|
| Basset-Mens & van der Werf (2005) | France | 3.0 | 73% crop / feed |
| **Southern Supply Chain** | **Australia** | **3.1** | 27% crop / feed<br>25 % waste stream |
| Dalgaard *et al.* (2007) | Denmark | 3.3 | 61% crop / feed |
| Cederberg & Flysjo (2004) | Sweden | 4.4 | NR |
| Cederberg & Darelius (2001), in Cederberg & Flysjo (2004) | Sweden | 5.5 | NR |
| **Northern Supply Chain** | **Australia** | **5.5** | 66% Methane from pond |
| Williams *et al.* (2006) | UK | 6.4 | NR |
| Weidema *et al.* (2008) | EU average | 11.2 | NR |

[1] CW is carcass weight, measured as Hot Standard Carcass Weight in this study. Allocation methods may restrict the comparability of these studies.

GWP from the northern Australian supply chain was dominated by methane emissions from the effluent treatment ponds (66% of GWP) highlighting the importance of the waste management system. This is not surprising, as primary treatment ponds in Australia are designed to treat volatile solids with an anaerobic treatment process which produces a large volume of methane as a by-product (APL, 2004). Higher ambient temperatures and longer retention times for Australian industry conditions will correspond to higher methane emissions, as reflected by the high MCF recommended in the Australian tier 2 GHG methodology. A similar trend was apparent for the southern supply chain, though to a lesser extent. In this system, nitrous oxide from the deep litter housing systems contributed more than 10% of GWP, while methane from the breeder system effluent treatment ponds contributed 14% of GWP.

In comparison to European studies (i.e. Basset-Mens and van der Werf 2005; Dalgaard *et al.* (2007), crop emissions contributed a lower proportion of GWP. This is in response to the lower nitrous oxide emission factors applied by the tier 2 GHG estimation methodology for Australia.

A simple scenario was run for each supply chain where primary ponds at the piggeries were covered and a simple flaring device fitted. The additional capital inputs for this management system were included in the scenario. It was assumed that no on-going inputs are required for the flaring system. This scenario reduced GWP at the northern supply chain to 2.3 kg $CO_2$-e/kg HSCW and to 2.7 kg $CO_2$-e/kg HSCW for the southern supply chain. The larger reduction in the northern supply chain is because all effluent in this system is treated using a liquid pond system and could be mitigated using this approach. In contrast the emissions from the southern supply chain showed a lesser reduction, because waste stream emissions were only mitigated at the breeder piggery.

## 5. Conclusions

The results suggest that GWP from pork production in two Australian supply chains is similar to other studies presented in the literature; however, comparison to other studies is difficult due to issues such as the handling of co-products. It should be noted that the functional unit 'HSCW' for this study is significantly different to 'retail' pork, having the head, feet and skin on the carcass. For this reason direct comparison with other species will not be valid without adjustment for differences in carcass processing.

The contribution analysis showed higher contributions from effluent lagoon emissions and lower contributions from feed inputs compared to the European studies reviewed. This is in response to the higher MCF for effluent lagoon methane emissions and lower nitrous oxide levels from grain production. When waste stream emissions were mitigated, emissions were lower than other literature values.

The comparison of deep litter and conventional housing showed that, for the current management systems, deep litter housing required lower energy inputs and resulted in lower GWP than pork produced from conventional housing. These GWP results were reversed when pond covering was used in both the supply chains.

It is important to note that the study is highly sensitive to the emission factors used in the piggery waste stream calculations. These emission factors have not been derived from Australian research and represent a major uncertainty in the project, corresponding to variation of -28% to +59% in GWP.

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