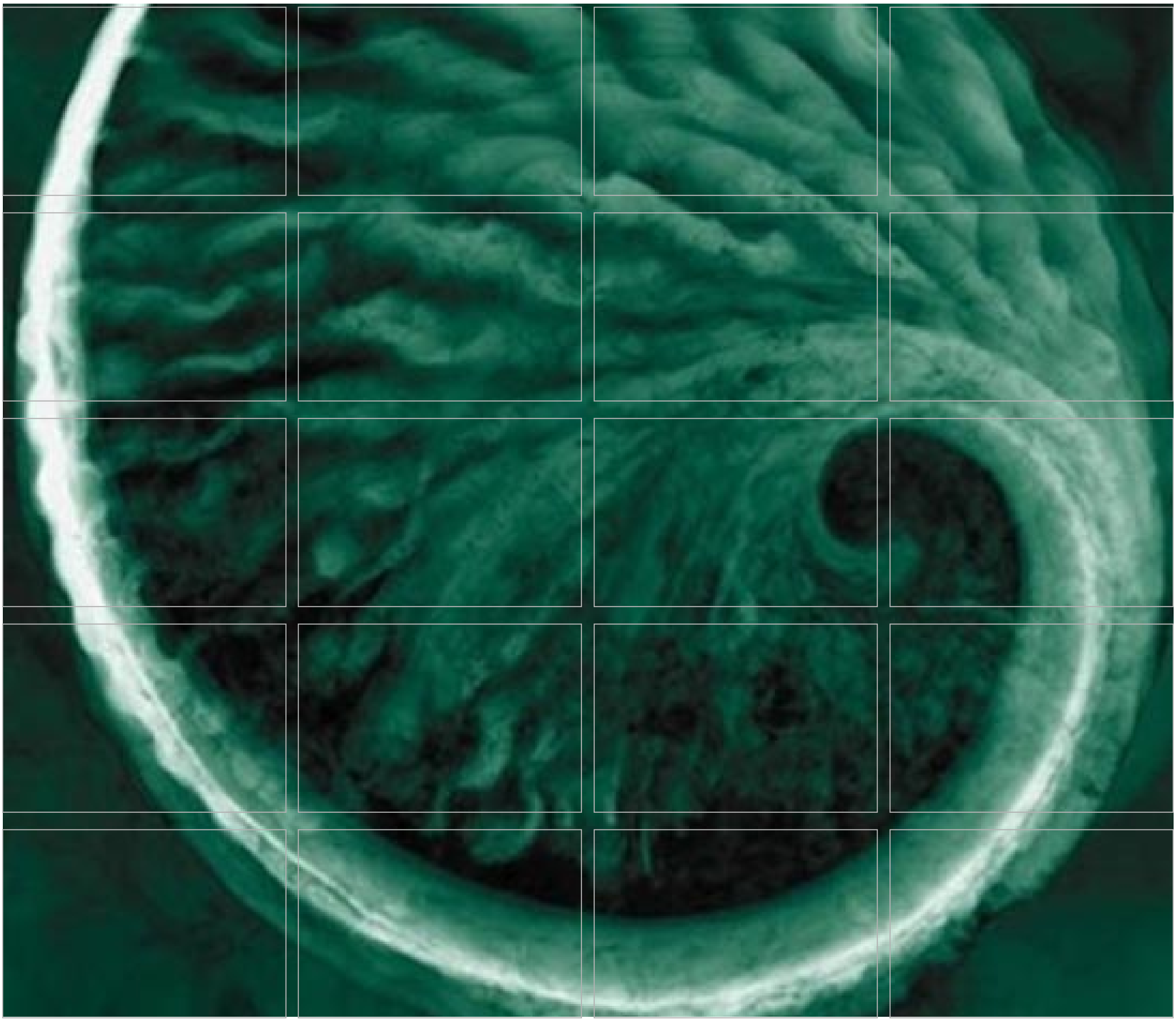

Scoping Life Cycle Assessment of Pork Production

Final Report

September 2009

Delivering sustainable solutions in a more competitive world

ERM

AHDBMS

Scoping Life Cycle Assessment of Pork Production

Final Report

September 2009

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For and on behalf of
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EXECUTIVE SUMMARY

Environmental Resources Management Limited (ERM) was commissioned by the Agriculture and Horticulture Development Board Meat Services (AHDBMS) to conduct a scoping Life Cycle Assessment (LCA) study in order to estimate the environmental impacts associated with pork products across their life cycle and to identify opportunities for improvement. The aim is to provide AHDBMS with a better understanding of the relative advantages and disadvantages of different pig farming methods and, in particular:

- indoor vs outdoor bred pigs;
- slatted floor vs loose bedding raised pigs; and
- compound- vs liquid-fed pigs.

It is intended that the study will aid AHDBMS in facilitating the communication of the environmental impacts of pork products.

The modelling undertaken as part of this study quantifies the impacts on: climate change; eutrophication; acidification; and abiotic resource depletion associated with the production, processing, packaging and its disposal, and consumption of one kg of pork product. The findings can be summarised as follows.

- Pig production (comprising feed production, pig rearing, and slurry and manure management and spreading on land) is the life cycle phase that contributes the most to the environmental profile of pork products. For example, for pigs raised indoor on slatted flooring, pig production accounts for almost three quarters of the pork product's contribution to climate change (also often referred to as carbon footprint).
- Of this, feed production is the element of pig production that makes the largest contribution. For example, the feed contributes 56% of the total carbon footprint of pork products from pigs raised indoor on slatted flooring.
- Storage in the home and preparation of the pork for consumption also contribute noticeably to the overall environmental profile of pork products. This is mainly in respect of the impact categories of climate change and abiotic resource depletion. These contributions are due to the energy consumed in the home for refrigerated storage of the pork and for subsequent cooking.

Comparison of different pig farming methods found that the farming methods of loose housing and outdoor breeding make significantly higher contributions to eutrophication and acidification than those systems where pigs are raised indoors on slatted flooring. A higher contribution is also seen for climate change in this case, albeit not one so significant. The higher impact is almost solely a result of higher emissions from both the housing unit and the application of manure to land compared to slurry from indoor slatted

flooring. The impacts of the manure account for more than 180% of those of the slurry for all of the impact categories assessed.

The outdoor manure was found to contribute less to climate change, eutrophication and acidification than slurry. However, since the outdoor farming method modelled as part of this study only considers outdoor breeding units with the rearing and finishing herd assumed housed indoor on loose bedding, the total impacts across the pork product life cycle show this to have the second largest environmental profile of the farming methods assessed.

Benchmarking with data provided by two producers (Producer A and Producer B) showed that a number of general farming efficiency factors, as achieved by the two producers, can reduce the environmental profile of the pork product considerably. For example, Producer A and B achieve carbon footprints that are 7% and 11% lower respectively than those for average British pork products. More efficient measures include: achieving more pigs per litter; lower feed conversion ratio; lower sow feed consumption; lower mortality; and lower sow culls. For Producer B, the use of a liquid co-product as part of the finisher feed also contributes to a lowered environmental profile.

A further reduction in impact is seen from pigs produced from Producer B as a result of the anaerobic digestion of slurry from the finishing herd before it is spread on land. Anaerobic digestion of slurry leads to significant savings with regard to climate change, eutrophication and acidification. These savings result from the generation of electricity, and thereby the avoidance of electricity produced from fossil fuels. It must be highlighted that the anaerobic digestion model is based on a number of assumptions. Despite these uncertainties, the figure demonstrates the benefit of recovering the energy held in the slurry before its application to land.

Further benchmarking was achieved for organic pork production in comparing data provided by an organic producer (Producer C) to BPEX data for conventionally produced pork product. This found that, in the case of Producer C, the organic pork product has higher environmental impacts per kg product than the non-organic pork based on slatted flooring, but delivers lower impacts than the non-organic British pork product from loose housed or outdoor bred pigs. Without data from other organic pig farmers, and further investigation of the underlying data provided by Producer C, it is difficult firmly to establish that organic pig farming has a lower environmental profile than conventional pig farming based on loose bedding.

In addition to the benchmarking exercise, "what if?" scenarios were developed and used to assess the environmental gains that could be achieved if the average British producer achieved the same performance results as the top third of producers, as presented in the Pig Year Book 2009. Such a raising of the bar would deliver benefits in the order of a 3.1% improvement in acidification, 3.8% improvement in eutrophication, 3.9% improvement in non-renewable energy consumption, and a 4.2% reduction in contributions to climate change.

The results reported above and presented in the report should only be seen as indicative. A scoping study like this uses readily available data in order to provide indicative estimates of the relative environmental performance of pig production in the UK. Extensive data collection and detailed modelling has not been carried out.

Nevertheless, the results show that, in considering the potential for improving the environmental impacts of British pork products, the main improvements can be achieved in the pig farming phase of the pork product life cycle. Evaluating the results in further detail suggest that the measures for achieving the greatest improvements are:

1. utilising feed as efficiently as possible;
2. achieving higher numbers of pigs per litter; and
3. managing the slurry/manure in ways that reduce its impacts.

Study limitations

The most important limitations to this study are identified as follows.

- This is a scoping LCA study. As such, readily available information and data is used in the form of pig farming data from the Defra research project *Determining the Environmental Burden and Resource Use in the Production of Agricultural and Horticultural Commodities* conducted by Cranfield University (subsequently called the Cranfield study) (Williams *et al* 2006) and the BPEX Pig Year Book 2009. Where there are missing data, these have been substituted with surrogate data or left as data gaps.
- Data reported in the Pig Year Book 2009 are reported according to outdoor or indoor breeding, however not according to wider farming methods such as fully slatted housing or loose bedding. As such, some variations in the farming method may not be accounted for.
- Secondary data, sourced from the Cranfield study, were used to model systems where data were not available from the BPEX Pig Year Book 2009. These data are considered to be the best currently available for UK pig production and suitable for use in this study. Nevertheless, it must be highlighted that the data are some years old now and a number of modelling assumptions are not fully described in the supporting material to the Cranfield model.
- The abattoir and meat processing data originate from a single processor. As such, the data for the slaughtering of the pig and processing of the pork meat may not be representative of the average British pork product. Another processor contacted was not in a position to supply data for this study.

- A recent report from the Waste and Resources Action Programme (WRAP) reports that consumers waste a significant proportion of food through not storing it correctly, using it in time, or throwing out leftovers. The report is not specific about the proportion of pork product wasted per quantity purchased. However, an average figure for food wastage in general of one third, as provided in the report, was used.

1 INTRODUCTION

1.1 BACKGROUND

Pork production and pig farming is receiving increasing attention in the UK from the likes of retailers, TV chefs, and the general public. This places a focus on the trade-off between the productivity of different farming methods and the impact these have on the environment and on animal welfare.

To this end, the Agriculture and Horticulture Development Board Meat Services (AHDBMS) wishes to understand the sources and scale of environmental impacts, and particularly releases of greenhouse gases contributing to climate change, across the life cycle of pork products.

The primary aim of this study is to estimate the environmental profile of British produced pork. To this end, the method of Life Cycle Assessment (LCA) has been used. To minimise the resources expended in the first instance, the project is limited to a 'scoping LCA'. This minimises the collection of primary data and employs readily available data wherever available. Although climate change is the main focus of this study, other environmental impacts that are important when considering pork production and pig farming are also considered, *viz*.: eutrophication; acidification; and abiotic resource depletion.

1.2 PROJECT OBJECTIVES

The overall aims of this study are threefold:

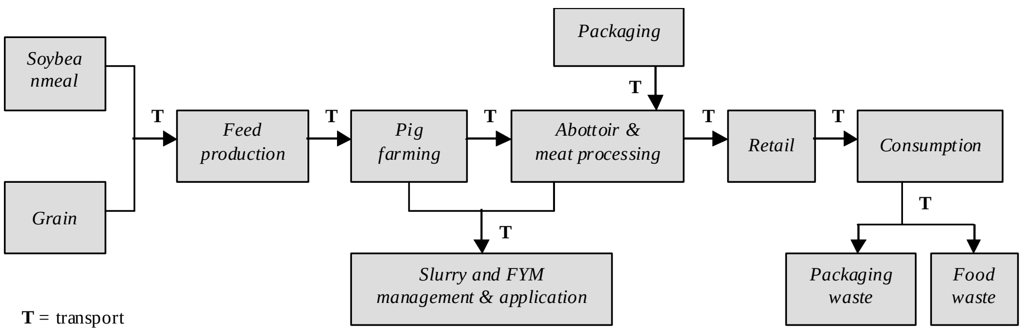
- to estimate the environmental impacts associated with pork products across their life cycle and to identify opportunities for improvement;
- to facilitate communication of these environmental impacts (in particular greenhouse gas emissions) with suppliers, and potentially with other stakeholders; and
- to inform decisions regarding any further data collection to validate secondary data used in this study and to improve the robustness of the model.

The life cycle assessment (LCA) method is used to estimate the environmental profile of British pork products.

The measure to which the results relate (the functional unit) is '1 kg of pork product as consumed by the consumer'. Due to a lack of data on the different pork processing methods, no distinction is made between the different types of pork (eg chop, bacon, sausages). For the purposes of this study, the pork products are all assumed to be fresh produce.

Figure 2.1 below summarises the pork product life cycle. Wheat, wheat feed, barley and soya bean meal are the main components of the feed. During the production of the feed, energy and water are consumed and substances are emitted from the growing of the crop, from harvesting and processing and from transport. The feed is consumed by the pigs during growth, and, in turn, animal excreta are managed as slurry and farm yard manure (FYM). These products are stored, and later applied to fields as a fertiliser. On reaching a certain weight, the pigs are brought to the abattoir where they are slaughtered and the meat is processed and packaged. The meat is then transported to retail outlets, via regional distribution centres (RDCs), where the product is purchased by the consumer. The meat is cooked by the consumer and consumed, and the packaging and any food waste is disposed of as general household waste.

Figure 2.1 Summary of the pork product life cycle



In order to understand the impact and benefits of choices made with regard to pig breeding methods, different scenarios are modelled and compared. The comparisons are:

- indoor vs outdoor bred pigs;
- compound- vs liquid-fed pigs; and
- slatted floor vs loose bedding raised pigs.

The pork product in this assessment represents British pork produced at an average British pig farm during 2007.

2.1 *DESCRIPTION OF THE DIFFERENT LIFE CYCLE STAGES OF PORK PRODUCTION*

In the following, the different life cycle stages are described in more detail.

2.1.1 *Feed*

Pigs are fed a pelletised compound feed, own-milled feed, or liquid feed (often called co-product feed) combined with dry (solid) feed.

Increased farm sizes and the need for automisation has made dry feeding the most common feeding method employed on British pig farms. Compound feed, as generally used in the UK, is factory produced by a couple of main suppliers. The feed is generally labelled with percentage ranges for the different feed ingredients. The main ingredients are wheat, wheatfeed, barley, and soybean meal.

Computerised feeding systems and lower costs have led to a revival in the use of industrial co-products from the human food industry. The type of liquid feed very much depends on the food processing industries in the vicinity of the individual farms, as transporting the liquid feed long distances is generally not economically viable. The most commonly known liquid feed is whey. Others include liquid potato, chocolate, yoghurt and brewery co-products. Some liquid feeds, such as derivatives from the cereal processing industry, are branded and sold under names such as Greenwich Gold and Abrocarb.

In accordance with the specific dietary and nutritional needs of the pig during its life cycle, the feed provided varies in terms of both its ingredients and quantity. Three different kinds of feed are considered in this study: feed for sows; for weaners; and for finishers.

It has not been possible to obtain detailed information about the exact feed combination through the feed producers contacted during this study, due to the commercially sensitive nature of the data. Consequently, the LCA data used for solid feed data in this study is drawn from the Cranfield study (Williams *et al* 2006). A comparison of recent Defra statistics and those used for developing the concentrate feedstuff models in the Cranfield study shows little difference in the mean distribution of main raw feeds used by feed blenders. Considering the wider uncertainties encompassed in the data and the models, the feedstuffs models of the Cranfield study are considered appropriate for use in this study.

The liquid feed used in the case study on different feed types is based on data provided by Producer B. The liquid feed is combined with a dry feed balancer on the farm. It was outside the scope of this study to model the life cycle impacts of the different food products for which the liquid feed is a co-product. Instead, environmental input output data[1] have been used, based on the cost paid by the farmer for the feed.

Table 2.1 below shows a dry matter (DM) based comparison of the LCA data for the different dry feeds and the liquid feed. As can be seen, the impacts of the liquid feed are considerably lower than those of the dry feed. This difference is to a large extent a reflection of the price paid by the farmer compared to the price of the main food product. It suggests a considerable environmental saving to the farmer when using liquid feed as part of the pig feed.

It should be noted that this is an example of liquid feed as it is based on data from one farm only. As such, the price that the farmers pay might vary considerably, based on the co-product and the demand for it. Finally, using a simplified method rather than modelling the food products in detail and allocating precisely to the co-product will inevitably lead to an inherent uncertainty in the modelling of the liquid feed.

Table 2.1 Comparison of LCA data for dry and liquid feed as per DM content *(normalised against non-organic dry feed for finishing herd)*

	Dry feed, sows, non-organic	**Dry feed, weaners, non-organic**	**Dry feed, finishers, non-organic**	**Liquid feed, finishers**
Data source	Williams et al 2006	Williams et al 2006	Williams et al 2006	ERM 2007
Climate change	88%	107%	100%	14%
Eutrophication	78%	113%	100%	4%
Acidification	82%	108%	100%	15%
Abiotic resource depletion	90%	103%	100%	3%

2.1.2 *Pig farming*

Pig farming has been divided into four separate processes representing: breeding herd; rearing herd; finishing herd; and sow replacement. The processes take into account both the feed production, the rearing of the pigs, the storage and management of manure/slurry, as well as application of these to the field.

To enable the comparison of different farming methods, the pig farming processes are altered according to whether indoor or outdoor pigs and whether slatted or loose housing are considered:

- indoor bred pigs, fed on dry feed:

[1] Economic input output (I/O) tables map the economic flows between sectors in an economy. Environmental I/O (EIO) data are developed when the economic I/O data are combined with environmental data for each industry sector. The results express the environmental load according to the unit value of a sector.

- fully slatted housing; or
- Loose housing (with straw bedding); or

- outdoor bred pigs, fed on dry feed.

In the UK, some 60% of pigs are bred indoors. Sows are housed for approximately 60 days per year in farrowing pens. When dry, the sows are generally housed in groups in larger pens. The piglets are weaned after three to five weeks, when they reach a weight of approximately 7 kg. The weaners are then moved to weaning pens where they spend some seven weeks until they reach a weight of 30 kg. The weaners are then move to larger finishing pens for a further 10 to 18 weeks until they reach a weight of approximately 100 kg. The pigs are kept in pens with either fully, or partly, slatted flooring, or with straw bedding. Slatted flooring allows pig manure to fall directly into a drainage system below the pens, draining to an on-site slurry management system. If straw bedding is used, once soiled, this is removed from the pens and used on the farm as farm yard manure.

The remaining 40% of UK pigs are bred outdoors. In the outdoor system, sows are housed outdoors with each sow having its own house in a fenced area, in which the piglets are born. Once weaning age is reached, the piglets are put into their own fenced areas. In the majority of outdoor farms, once the weaned pigs reach finishing age, they are moved indoors. Pigs bred and grown organically are often finished indoors[1]. Buildings for finishers in an outdoor or organic system will generally contain loose bedding rather than slatted flooring.

Alongside pig rearing for pork production, sow replacements are produced. These replacement sows substitute the breeding sows that come to the end of their productive life, or for some other reason are culled.

The outdoor bred pig model considers only an outdoor breeding herd. The rearing and finishing herd, and the sow replacement, are all assumed to be indoor loose housing.

Table 2.2 ***Physical performance modelled***

	Indoor bred, non-organic	**Outdoor bred, non-organic**
Pigs weaned per sow per year	22.0	20.3
Sow feed (kg) per sow per year	1334	1584
Average live weight at slaughter (kg)	101.6	101.6
Finishing mortality (%)	3.3	3.3
Sow culls (%)	41.6	41.8
Rearing feed conversion ratio	1.74	1.77
Finishing feed conversion ratio	2.87	2.74

Source: Pig Year Book 2008.

No national data have been identified for pig farming using liquid feed as part of the feedstuff. As such, this farming method is only assessed through a benchmark case study.

During pig production, inputs to the farm are required in the form of feed, energy, and potentially bedding. This is reported for each farming method in *Table 2.3* below, along with outputs and emissions.

Table 2.3 Inventory for pig farming (per individual pig output)

	Indoor bred pigs, dry feed, fully slatted housing	Indoor bred pigs, dry feed, loose housing	Outdoor bred pigs, dry feed
Inputs			
Feed (kg)	383	344	371
Straw (kg)	0.00418	0.207	0.211
Electricity (kWh)	45.1	42.6	30.6
Outputs			
Pig (live weight) (kg)	101.6	101.6	101.6
Slurry (kg)	767	0	0
Farm yard manure, FYM (kg)	15.4	969	988
Emissions			
Ammonia (kg NH_3)	1.34	1.33	1.77
Nitrous oxide (kg N_2O)	0.00814	0.00715	0.00743
Methane (kg CH_4)	2.00	2.45	2.31

The quantity of feed consumed is calculated based on 2007 data supplied by the farming industry to Agrosoft Ltd and subsequently collated in the Pig Year Book (BPEX 2008). Straw and electricity use, slurry and farm yard manure (FYM), and emissions are calculated using the Cranfield model (Williams et al 2006).

2.1.3 Transport to abattoir

An average distance for the transport of British finisher pigs from the farm to the abattoir has been estimated as 82.6 km (Hansard 27 July 2007). Based on data provided by the farmers contributing to this study, it is assumed that each lorry carries on average 115 finisher pigs.

2.1.4 Abattoir and meat processing

Data for the abattoir processes and meat processing has been provided by Bowes of Norfolk. The data are representative of 2008. The data represent the plant as a whole and cannot be broken down into slaughtering processes and meat processing. Accordingly, the data represent an average meat product as it is not possible to break the data down according to product (bacon, sausage, pork loin, etc). The data are confidential.

Bowes assumes an average deadweight of 75 kg. With the waste quantities reported, this suggests a liveweight of 91 kg. However, this figure includes waste generated from meat processing. In reality, the liveweight of the pigs processed at Bowes of Norfolk may be lower.

Manure and slurry from abattoir holding pens is applied to land. Offal is sent for rendering as pet food and the blood is injected into land as a fertiliser. The remaining waste is sent for landfill.

To model the packaging required, it has been assumed that the pork product is packaged in 600 g portions in a plastic tray with lid and a paper label. Based on ERM in-house data the packaging weights have been selected as shown in *Table 2.1* below. The transit packaging is assumed to be reusable and consisting of a reusable plastic tray and pallet.

Table 2.4 Packaging assumptions for the purpose of this study

	Packaging data
Primary packaging	
Plastic tray (polypropylene, PP)	14 g
Plastic lid (low density polypropylene, LDPE)	2.5 g
Paper label	1.6 g
Pork product per primary packaging	600 g
Secondary and transit packaging	
Produce tray (high density polypropylene, HDPE)	1.6 kg
Pallet (high density polypropylene, HDPE)	16 kg
Pork products per tray	15
Trays per pallet	90
Produce tray reuses	50
Pallet reuses	20

2.1.5 Distribution to retail

Refrigerated distribution of pork products to retail has been estimated due to a lack of concrete data. Based on ERM in-house data it is assumed that the average distance to the RDC is 230 km, with a further 65 km to the retail shop. It is assumed that refrigerated storage at the RDC is on average one day.

2.1.6 Retail

Based on ERM in-house data, it is assumed that the pork product on average is held in store for one day before being purchased by the consumer. The retail process accounts for the refrigeration required for this time period.

2.1.7 *Transport from retail to the home*

Pretty (Pretty et al 2005) calculated, based on UK government statistics, that food shopping for a UK household involved about 8 km of car travel per household per week (as well as some travel by bus, bicycle and on foot). The food expenditure survey suggests that food consumption is about 12 kg per person per week. With an average UK household size of 2.32 persons, this equates to 28 kg per household per week. Of course, non-food items are also purchased in supermarkets. However, these are excluded for the purposes of this exercise due to a lack of data.

For this study, the pork product's contribution to the environmental impacts for transport to the home has been calculated based on the following assumptions:

- only car travel is considered;
- an 'average' car is assumed;
- the only purpose of the car trip is food shopping;
- the average journey from the home to the supermarket is a 8 km roundtrip; and
- each household purchases on average 28 kg food per food shopping trip.

2.1.8 *Consumer*

Once the pork product has been transported home by the consumer, it is likely that it will be stored in the fridge or freezer for some time before being cooked and consumed. For the purposes of this study, it is assumed that the pork product is stored in the refrigerator for three days before cooking. Roasting is assumed as the cooking method for the purpose of this scoping study.

A recent study by WRAP found that a third of the food we buy is thrown away. Most of this could have been eaten if it had been stored correctly, used in time, or if leftovers had been saved for another day. The study does not provide specific percentage data for pork products wasted per quantity purchased. However, other statistical information of pork product wastage is provided. For example, the report mentions that 1.2 million sausages are thrown away every day in the UK.

Due to lack of data for pork product wastage useable for this study, it has assumed that one third of the pork purchased by the consumer is not consumed. As such, in order to fulfil the functional unit of '1 kg of pork product as consumed by the consumer', the consumer has to purchase 1.3 kg. The effect of this is felt all the way up the supply chain in terms of increased impacts incurred in delivering the functional unit.

The waste management impacts of the pork waste have not been in this study due to lack of data on meat degradation in landfill and meat combustion in energy from waste plants.

3 RESULTS

The four environmental impact categories against which the results are reported can be described as:

- **Climate change potential** is an increase in temperature caused by the emission of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere. The results are expressed in kg CO_2 equivalents and represent a time horizon of 100 years.
- **Eutrophication potential** is a reflection of the amount of nutrients (eg nitrate and phosphate from manure/slurry) leached to the aquatic environment. Nitrates and phosphates are essential for life but increased concentrations in the aquatic environment can cause excessive growth of algae, reducing the oxygen within the water and damaging ecosystems. The results are expressed in kg phosphate (PO_4^{3-}) equivalents.
- **Acidification potential** relates to the release of acidic gases (eg ammonia from slurry/manure, or sulphur dioxide (SO_2) from the combustion of fossil fuels), which have the potential to react with water in the atmosphere to form 'acid rain', resulting in reduced pH in natural habitats (eg lakes) and thereby causing ecosystem impairment. The results are expressed in kg SO_2 equivalents.
- **Abiotic resource depletion potential** estimates the extraction of scarce minerals and fossil fuels. An abiotic depletion factor is determined for based on the remaining global resource reserves and their rates of deaccumulation. The results are expressed in kg antimony (Sb) equivalents.

3.1 ENVIRONMENTAL IMPACT OF BRITISH PORK FROM INDOOR PIG FARMING, SLATTED FLOORING

The environmental profile per kg of British pork product using the indoor farming method of slatted flooring is shown in *Table 3.1* below.

Table 3.1 Environmental profile of British pork product, indoor pig farming, slatted flooring, per functional unit

Impact category	**Unit**	BPEX, indoor, slatted flooring, non-organic
Climate change potential	kg CO_2 eq.	8.6
Eutrophication potential	kg PO_4^{3-} eq	0.057
Acidification potential	kg SO_2 eq	0.19
Abiotic resource depletion potential	kg Sb eq	0.053

As stated previously, the results should be seen as indicative only. This is a scoping study and as such readily available data have been used in order to provide indicative estimates of the relative environmental performance of UK pig production.

The results are described in further detail below.

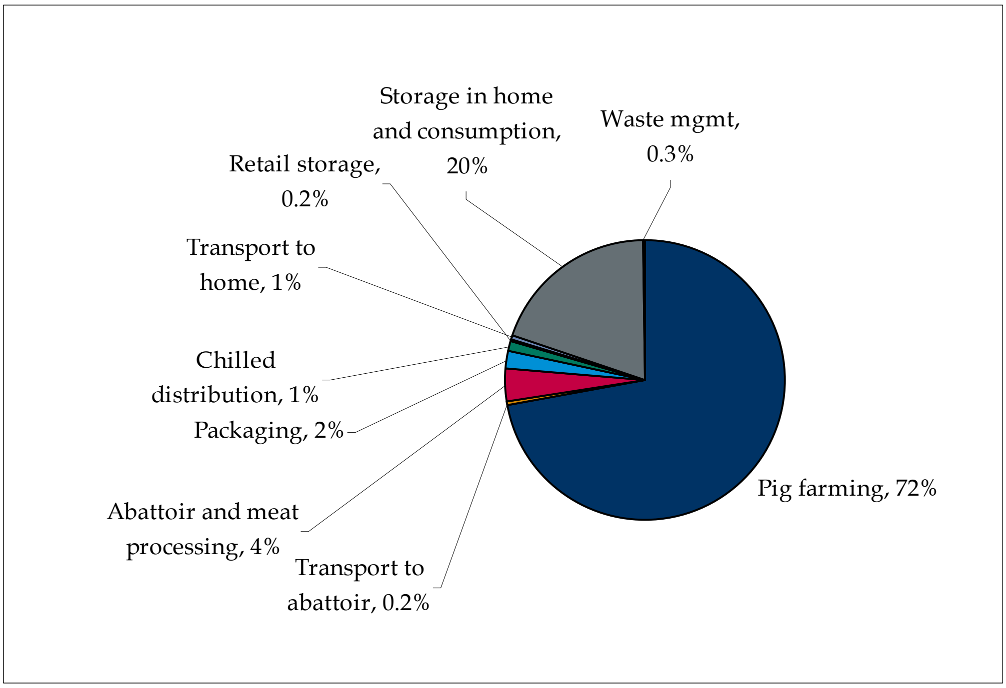
3.1.1 Climate change potential

Emissions contributing to climate change, or the carbon footprint, per kg pork product consumed, are 8.6 kg CO_2 equivalents. *Figure 3.1* shows how each stage of the life cycle contributes to the total carbon footprint of the pork product produced from indoor pig farming using slatted flooring.

From the results of the carbon footprint, the following key findings can be highlighted.

- Pig production (comprising feed growing and production, pig rearing, and slurry/manure management) has the greatest contribution to climate change, accounting for almost three quarters of the pork product's carbon footprint.
- Storage in the home and preparation of the pork product for consumption (roasting) accounts for 20% of the total carbon footprint. This may be unexpected. However, food preparation in the home is generally an inefficient way of preparing food.
- Abattoir processes and meat processing account for only 4% of the total carbon footprint, or 0.35 kg CO_2 eq. The main contribution in this stage, accounting for almost two thirds of the climate change impacts, is the electricity consumption for processing and chilled storage of the meat. The rest of the climate change impact largely results from the energy required to heat water.
- Transport and distribution throughout the life cycle, retail storage, packaging and disposal at end of life accounts for only 4.2% of the carbon footprint.

Figure 3.1 ***Contributions to life cycle carbon footprint of British pork product (indoor pig farming, slatted flooring)***



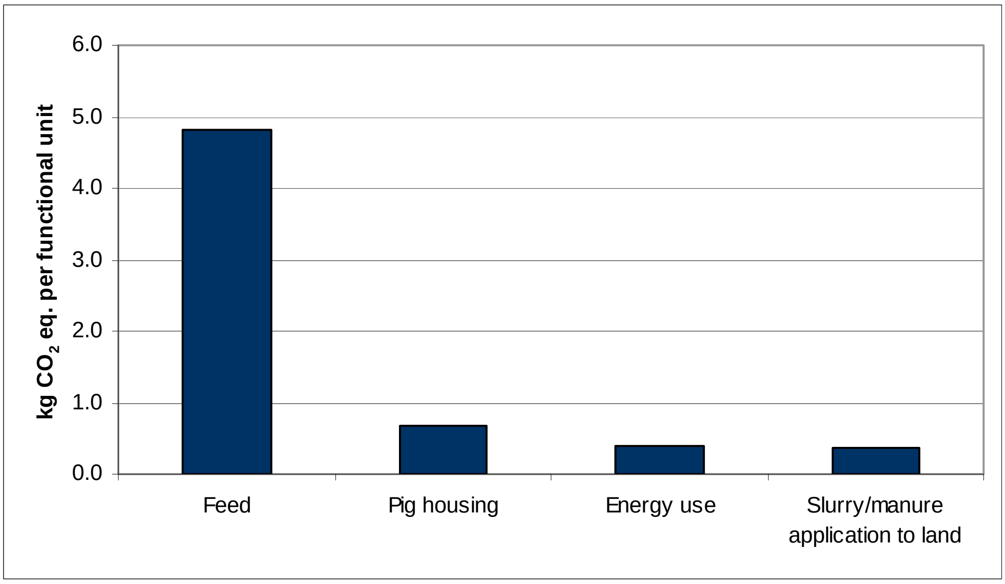
Further assessment of pig farming shows that the impacts of the finishing herd accounts for 43% of total impacts, the rearing herd 15%, the breeding unit 13%, and sow replacement 2%.

Figure 3.2 shows that pig feed contributes a considerable proportion of the carbon footprint of pig farming, and therefore of the full product chain. Feed contributes 4.8 kg CO_2 equivalents, which is 56% of the total carbon footprint of the pork product. The greenhouse gas emissions per kg feed as used in this study range between approximately 0.82 and 0.99 kg CO_2 eq (depending on whether it is sow feed, rearing herd or finishing herd feed). Since approximately 313 kg of feed is required to raise one pig, it is not surprising that the feed accounts for a significant proportion of the carbon footprint.

The impacts from pig housing are essentially resulting from the emission of ammonia, nitrous oxide and methane from the housing of the slurry and, in the case of methane, also from enteric fermentation from the pigs themselves.

Electricity use is estimated, based on the Cranfield model, as no average electricity consumption data for British pig farming have been identified. For indoor pig farming, it is assumed that only electricity is used, including for the provision of heating.

Figure 3.2 ***Contribution to the life cycle carbon footprint from the different stages of pig farming*** *(per functional unit)*



The contribution from slurry application to land is relatively small, because the need for less artificial fertiliser has been taken into account. The production and distribution of artificial fertiliser has environmental impacts and therefore when fertiliser is substituted by slurry or manure, the greenhouse gas emissions of artificial fertilizer are avoided. Because they are avoided, these are subtracted from those emitted from slurry/manure and its application.

As shown in *Figure 3.1* above, the climate change 'hot spots' in the life cycle of British pork products occur in the farming phase as well as the use (consumption) phase. In the farming phase, feed in particular makes a significant contribution.

3.1.2 Eutrophication potential

One kg of pork product from indoor bred pigs on slatted flooring has an estimated eutrophication potential of 0.057 kg PO_4^{3-} equivalents. The contributions to eutrophication originate almost solely from the farming phase of the product chain of the pork product, as shown in *Figure 3.3*, and amount to 0.055 kg PO_4^{3-} equivalents. The rest of the life cycle, combined into a single figure for all the processes from the farm gate to consumption and final disposal of the packaging, accounts for only 4% of the total contribution to eutrophication.

The most important pig farming contributions to eutrophication are nitrate, ammonia, nitrogen oxides, and, to a limited extent, phosphate.

Figure 3.3 ***Contributions to life cycle eutrophication potential of British pork product (indoor pig farming, slatted flooring)***

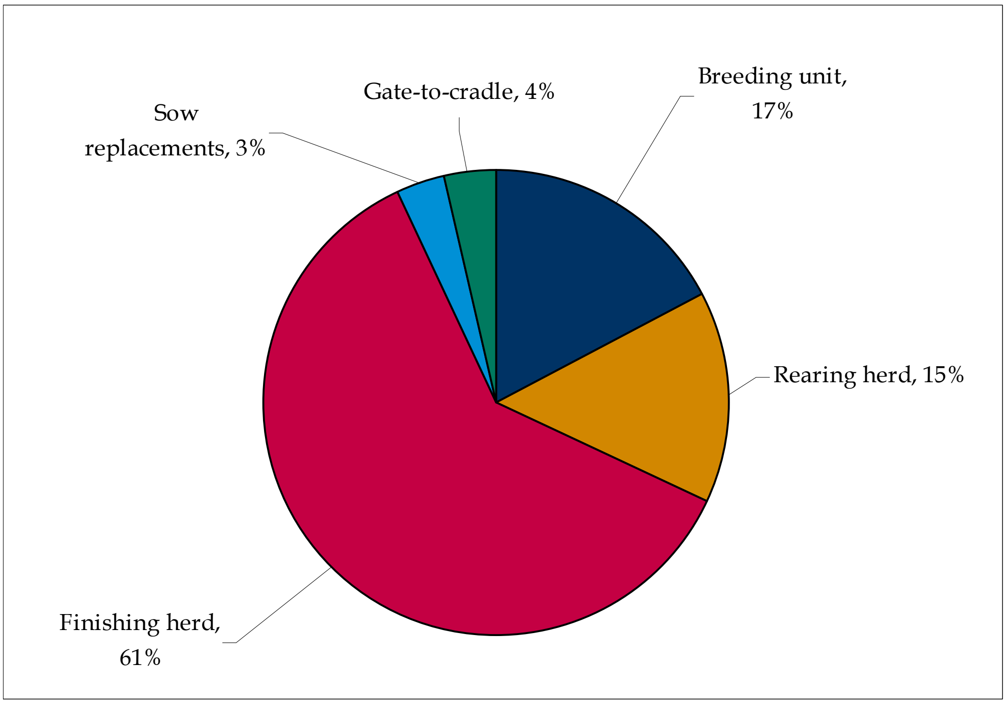
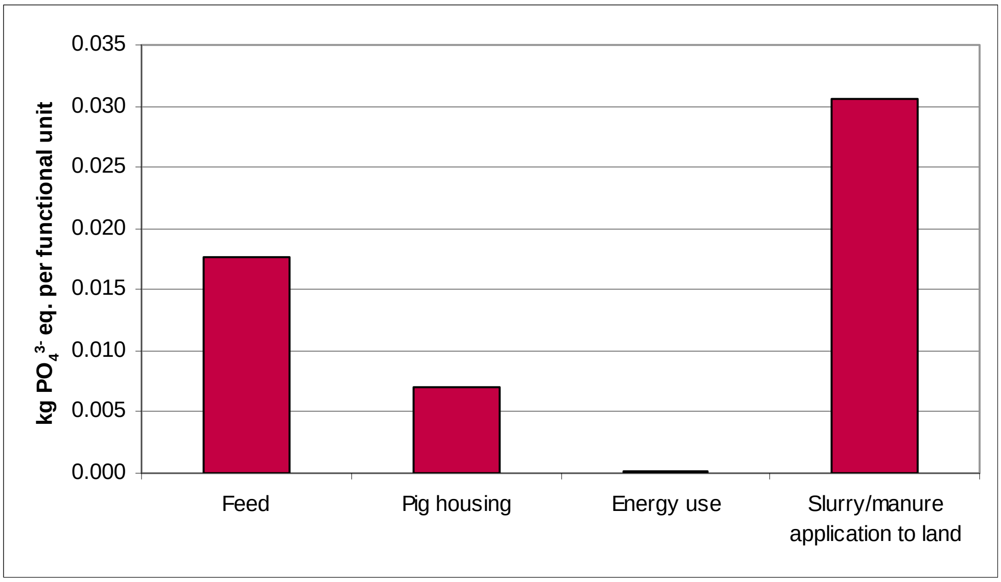


Figure 3.4 below shows that the highest contribution to eutrophication is slurry/manure application to land. Its contribution is 0.031 kg PO_4^{3-} equivalents, accounting for 53% of the total eutrophication potential. A significant contribution to this is the nitrogen in the slurry/manure not taken up by the crop. Instead, this is leached to watercourses and groundwater. Pig feed contributes 0.018 kg PO_4^{3-} equivalents, accounting for approximately 31% of the total eutrophication potential. Nitrate and ammonia emitted during cultivation of the feed components make the major contributions. The single contribution from pig housing is ammonia from slurry/manure in the housing units and from its storage. The contribution from energy use on the farm is very low.

Therefore, the key areas for focus when considering eutrophication are the management of nitrogen through the reduction of nitrate leached from fields and ammonia emitted from the slurry.

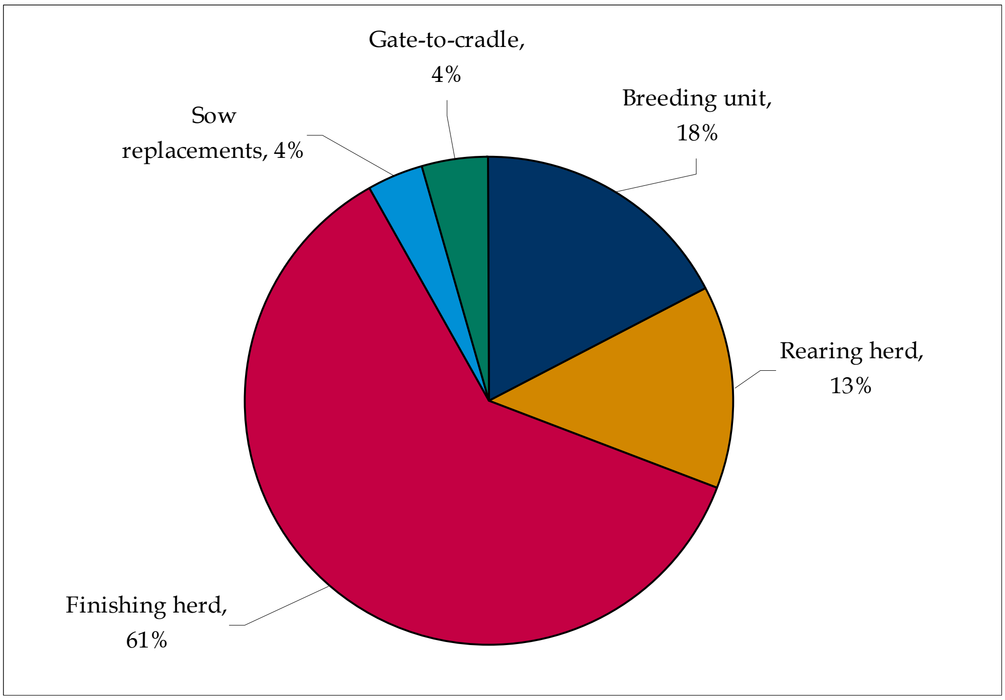
Figure 3.4 ***Contribution to life cycle eutrophication potential from the different stages of pig farming***



3.1.3 *Acidification potential*

Similar to eutrophication, contributions to acidification originate almost solely from the farming phase, as shown in *Figure 3.5*, amounting to 0.18 kg SO_2 equivalents compared to a total of 0.19 kg SO_2 equivalents. The rest of the life cycle accounts for only 4% of the total contribution to acidification.

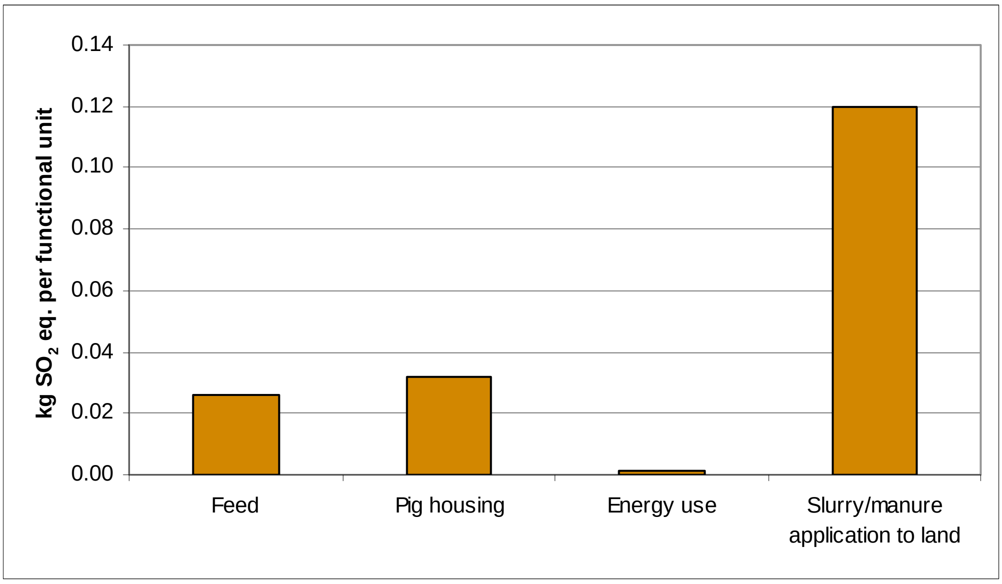
Figure 3.5 ***Contributions to life cycle acidification potential of British pork product (indoor pig farming, slatted flooring)***



Ammonia makes the major contribution to the life cycle acidification potential. Other contributions, such as nitrogen oxides, sulphur oxides and sulphur dioxide, which arise from energy production, are much less significant to this impact category.

The main contribution to the acidification potential comes from ammonia emitted from slurry/manure application to land. This accounts for 64% of the total acidification potential. Pig housing contributes through the emission of ammonia from the slurry/manure management. Some contribution is also seen from the feed. This is mainly from the soya meal due to the transport of this from South America and the associated emissions as well as the processing of feed.

Figure 3.6 ***Contribution to the life cycle acidification potential from the different stages of pig farming***

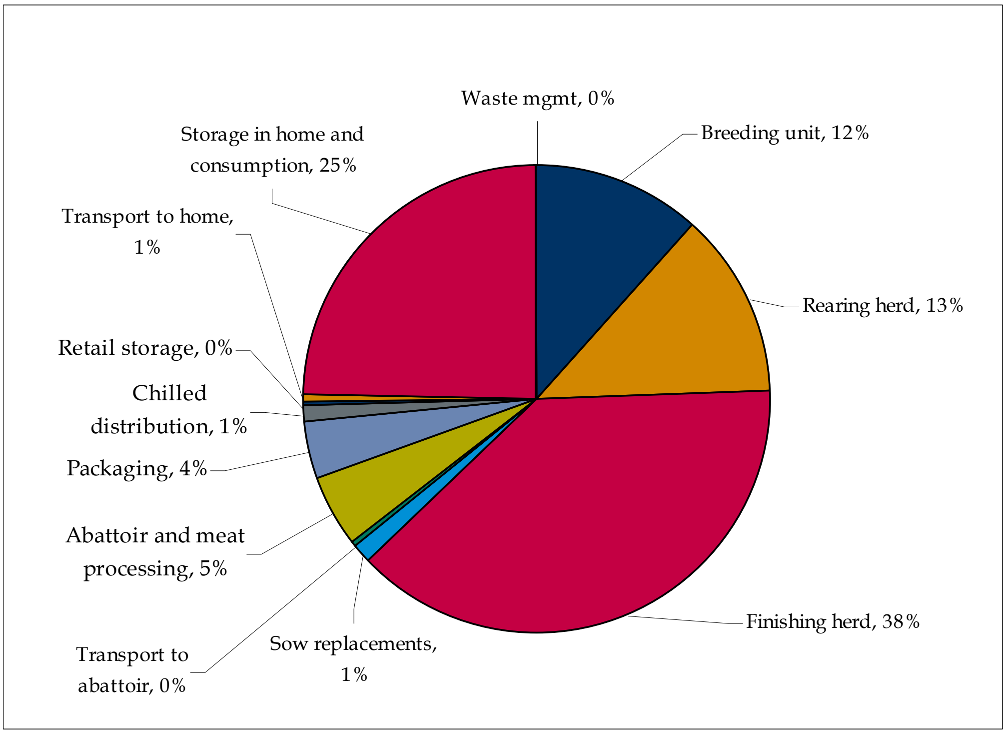


3.1.4 *Abiotic resource depletion potential*

Abiotic resource depletion is the depletion of fossil resources such as oil, natural gas and coal. One kg of pork product consumed from indoor bred pigs on slatted flooring has an estimated abiotic resource depletion potential of 0.053 kg Sb equivalents.

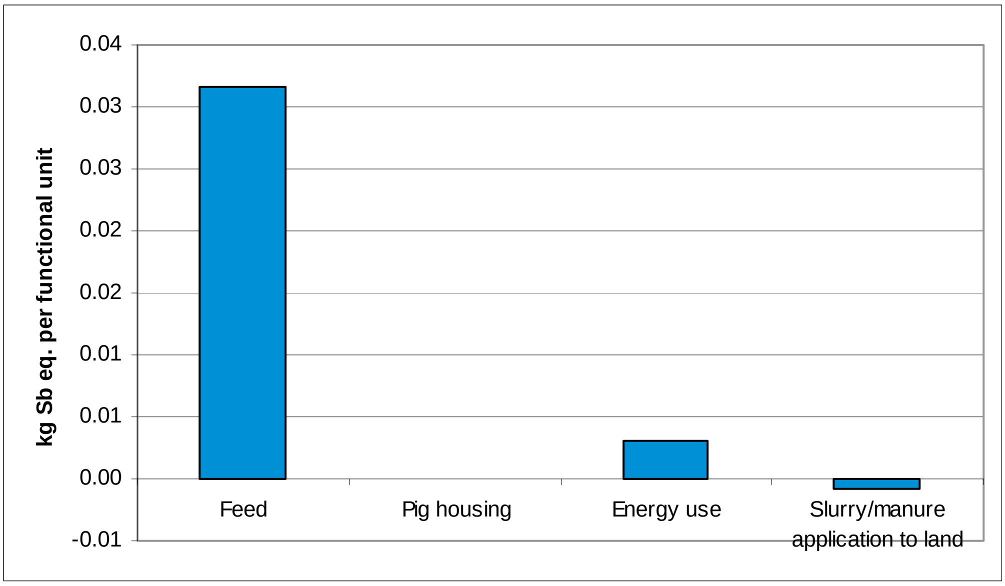
Similar to the other impact categories assessed, a significant proportion of the contributions to abiotic resource depletion originate from the farming phase of the product chain of the pork product as shown in *Figure 3.3*. These amount to 0.034 kg Sb equivalents (64% of the total life cycle impacts). Another significant contribution comes from the use (consumption) phase, with 0.013 kg Sb equivalents or 25%. The rest of the life cycle accounts for only 11% of the total.

Figure 3.7 ***Contributions to the life cycle abiotic resource depletion potential of British pork product (indoor pig farming, slatted flooring)***



The contribution from the use phase is due to the energy use in storing and cooking the pork product and is an indicator of the fossil fuel used for electricity generation.

Figure 3.8 ***Contribution to the life cycle abiotic resource depletion potential from the different stages of pig farming***

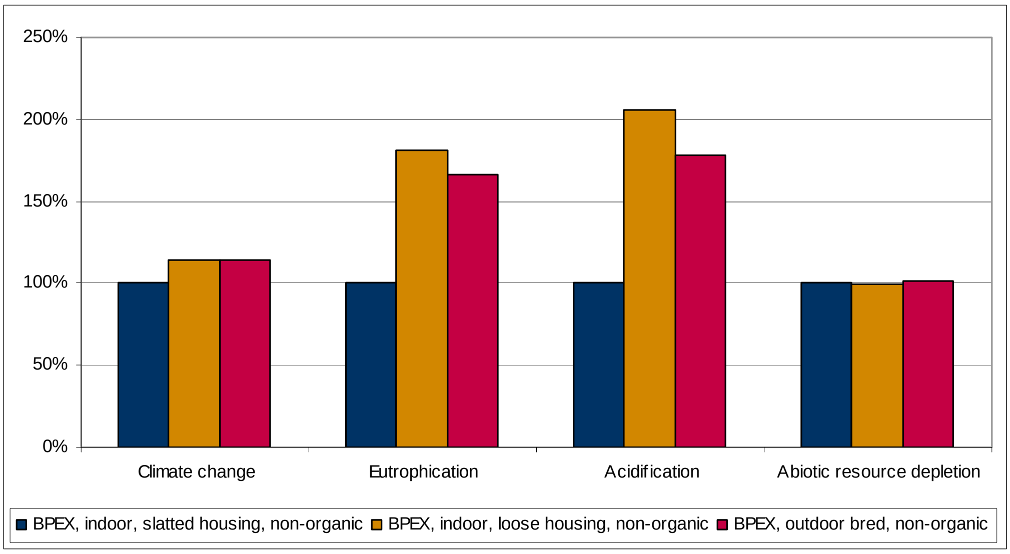


As shown in *Figure 3.8*, the main contribution from the pig farming phase comes from the feed. Again, this is mainly due to the transport associated with crop production and distribution, as well as with feed processing. A small contribution is also seen from energy use on the farm. The overall contribution from slurry/manure application to land is 'negative', because less abiotic resources are used when applying slurry/manure to the fields compared to the artificial fertiliser that is substituted.

3.2 COMPARISON OF DIFFERENT PIG FARMING METHODS

In the following section, British pork product from pigs raised indoor on slatted flooring (as shown in the previous section) is compared with pigs raised indoor on loose bedding and outdoor bred pigs, followed by indoor rearing on loose bedding. The models are based on data from the BPEX Pig Year Book 2008, combined with data from the Cranfield study.

Figure 3.9 Comparison of different pig farming methods



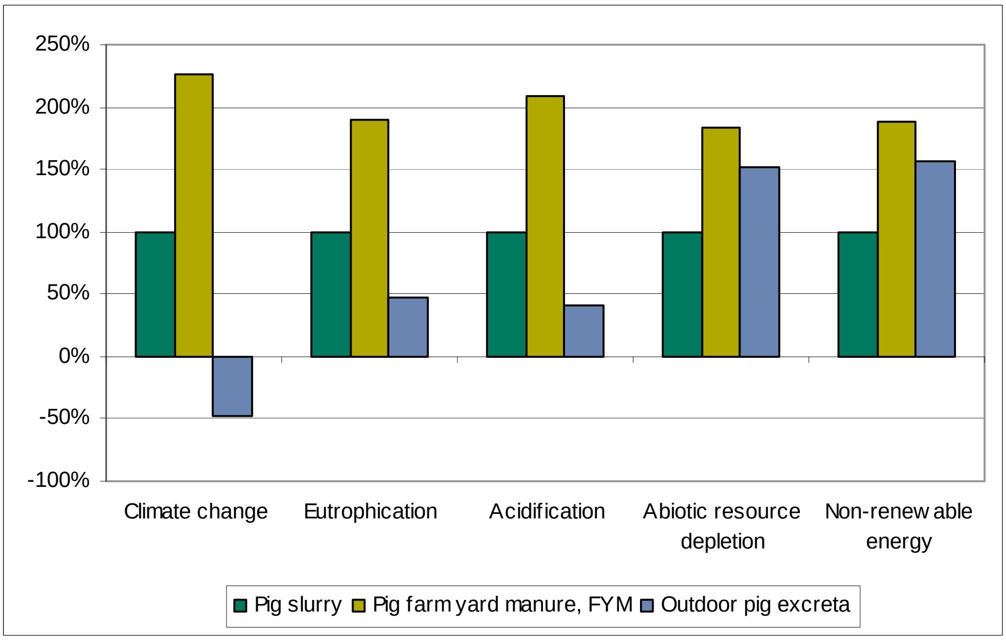
As can be seen from *Figure 3.9*, the loose housing and outdoor breeding methods make a significantly higher contribution to eutrophication and acidification than pigs raised indoor on slatted flooring. A higher contribution is also seen for climate change, albeit not as significant. Abiotic resource depletion is similar for all three farming methods.

The higher impact is almost solely a result of the emissions from the pig housing and the application to land of manure from loose housing and outdoor breeding compared to slurry from indoor slatted flooring. *Figure 3.10* below presents a comparison of the impacts of the application to land of slurry, farm yard manure and outdoor bred pig excreta, as taken from the Cranfield model.

As can be seen, the impacts of the manure account for more than 180% of those of the slurry for all of impact categories assessed. Slurry is to some extent diluted by spillage of drinking water by the animals. This may have been taken into account in the Cranfield slurry model.

In the Cranfield model, the outdoor pig excreta have lower impacts than the slurry for the impact categories of climate change, eutrophication and acidification. However, since the outdoor farming method considered as part of this study only considers outdoor breeding units, with the rearing and finishing herd assumed housed indoor on loose bedding, the total impacts across the pigs' life cycle show this to have the second largest environmental profile of the farming methods assessed.

Figure 3.10 *Comparison of slurry and manure impacts as used in this study*



3.3 BENCHMARKING OF SPECIFIC FARMING DATA AGAINST AVERAGE BRITISH DATA

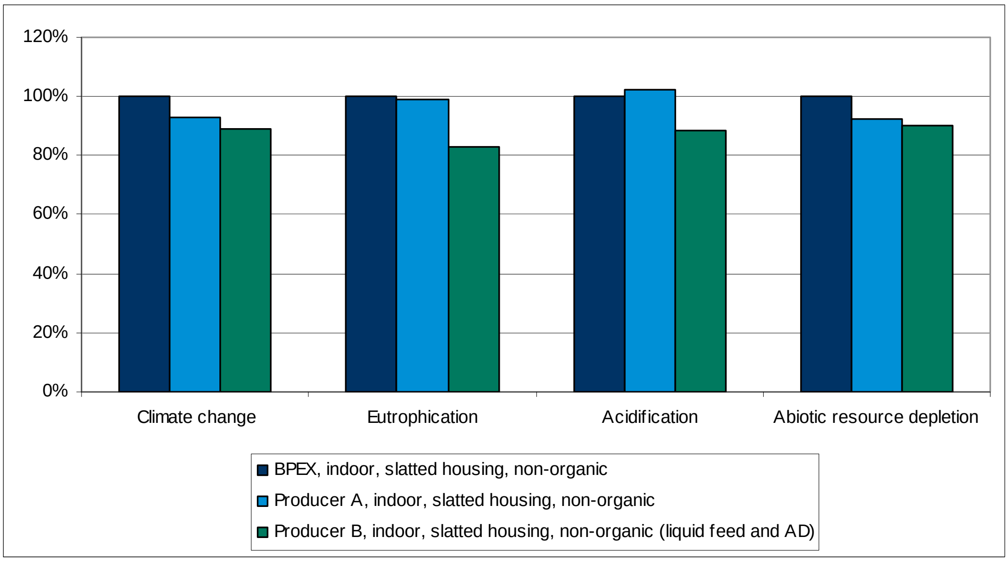
Data were received from three pig producers to facilitate benchmarking against results generated using BPEX Pig Yearbook data. These were two producer of conventionally bred pigs (Producer A and B) and an organic producer (Producer C). The pigs produced by Producer A are raised indoor on slatted flooring, ie similar to that of the baseline scenario assessed in *Section 0*. Producer B also raises his pigs indoor on slatted flooring (with the sows raised on loose bedding). However, the finishing herd is co-fed liquid feed and the slurry from the finishing herd undergoes anaerobic digestion before application to land. From Producer C, data were obtained for organically grown pigs raised outdoors, albeit finished indoors.

As stated previously, the results should be seen as indicative only.

3.3.1 *Benchmarking of different farms using indoor pig raising on slatted flooring*

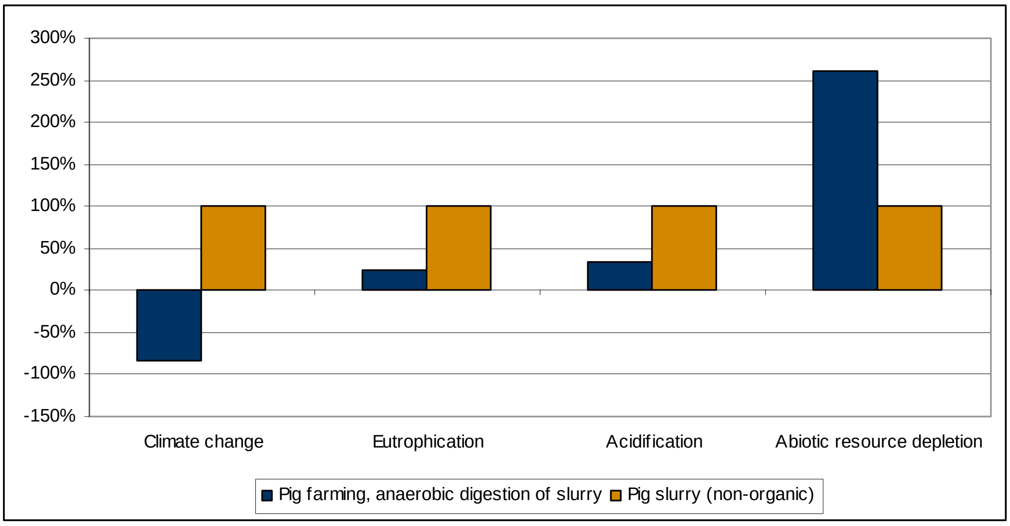
In *Figure 3.11* below, the results for Producer A and B are compared to those of the BPEX data for indoor bred pigs on slatted flooring. Both producers achieve lower impacts per kg pork product than the average British pork product (based on BPEX data), except for the impact category of acidification where Producer A has a higher score. In the case of both producers, the lower environmental profile is due to a number of general farming method factors, such as achieving more pigs per litter, lower feed conversion ratio, lower sow feed consumption and, in the case of Producer A, lower mortality and lower sow culls and, in the case of Producer B, the use of liquid co-product as part of the finisher feed. The lower feed conversion ratio means that, for example, whilst for the average British finishing pig to gain 50 kg, 143.5 kg of concentrate feed is required, Producer A and B achieve the same gain with 115.9 kg concentrate feed, and 112.8 kg concentrate feed and 303.5 kg liquid feed respectively. These figures are the quantities actually used, ie they are not dry matter corrected.

Figure 3.11 *Benchmarking of farming methods: indoor, slatted flooring*



The lower impacts of Producer B's pigs are due to the anaerobic digestion of the slurry from the finishing herd. *Figure* 3.12 shows that anaerobic digestion of slurry leads to significant savings with regard to climate change, eutrophication and acidification. This is due to the generation of electricity, and thereby the avoidance of electricity produced from fossil fuels. It should be highlighted that the anaerobic digestion model is, to some extent, based on assumptions and to verify its environmental benefits it is suggested to obtaining further information about the plant operation and in particular the digestate. However, despite these uncertainties, the figure demonstrates the benefit of recovering the energy held in the slurry before its application to land.

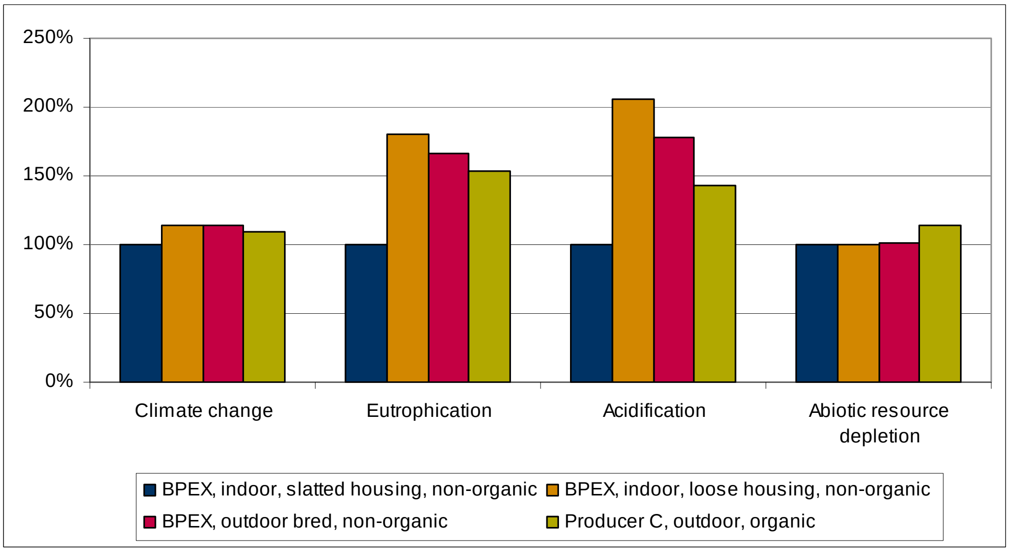
Figure 3.12 ***Comparison of slurry application to land and anaerobic digestion followed by application to land***



3.3.2 *Benchmarking of organic farming against conventional farming*

In *Figure 3.13* below, the results for Producer C's organic pork product are compared to those of the BPEX data for conventionally produced pork product. The organic pork product has higher environmental impacts per kg product than the non-organic pork based on slatted flooring but achieves lower impacts than the non-organic British pork product from loose housed or outdoor bred pigs.

Figure 3.13 ***Benchmarking of farming methods: organic against non-organic***



This is an interesting finding that may not necessarily correspond with findings in other similar studies. This may be partly due to the tighter standards in the UK for organic pig production.

Comparing the manure production reported by Producer C with that estimated in the Cranfield study, the quantities achieved on Producer C's farm are significantly lower. However, it must be highlighted that the quantity in the Cranfield study very much seems like an estimate.

Before making firm conclusions about organic farming, this farming method and the manure production would therefore be worthy of further consideration and verification.

3.4 "WHAT IF?" SCENARIOS

In addition to the benchmarking exercise, "what if?" scenarios were created to assess the benefits achieved if the pigs produced, feed conversion rate, mortality rates, etc achieved by the top third of producers represented the UK average.

Only the farming method of indoor bred pigs on slatted flooring has been considered. Similar results would be achieved for the other farming methods.

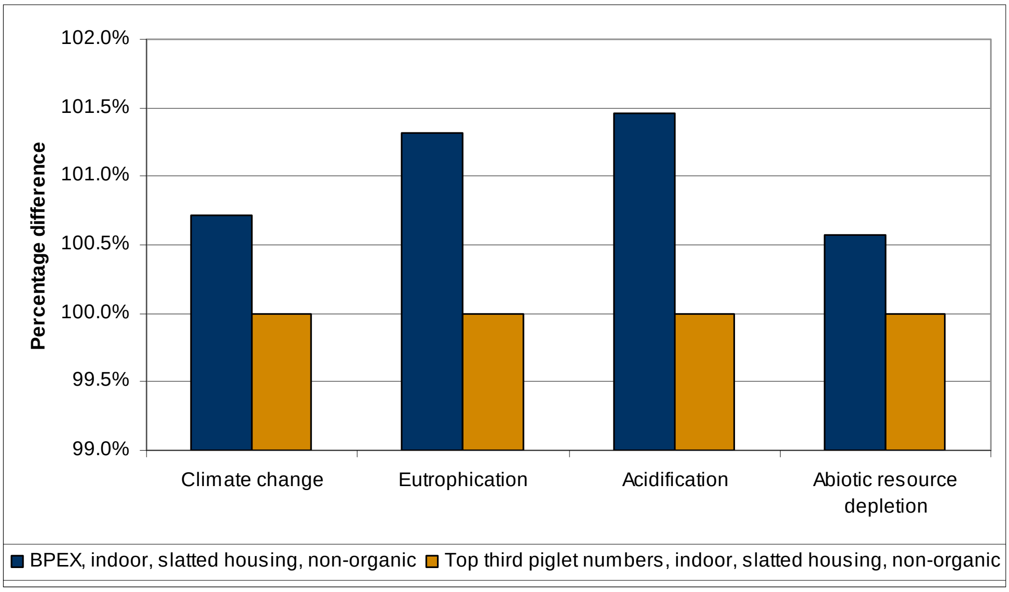
As stated previously, the results should be seen as indicative only.

3.4.1 What if the number of pigs produced per sow is the same as the top third?

In 2008, the top third of producers produced an average of 24.85 pigs per sow per year compared to a British average of 22.89 pigs per sow per year. It is assumed that this is partly achieved through the higher sow feed consumption of 1387 kg per year for the top third of producers compared to the British average of 1334 kg, and the higher replacement percentage of 47.67% compared to the British average of 45.53%. This has therefore been taken into account in the assessment.

The benefits of achieving the same number of pigs per sow as the top third producers are shown in *Figure 3.14* below. The benefits achieved range from a 0.6% improvement in abiotic resource depletion to a 1.4% improvement in acidification impacts.

Figure 3.14 ***Benefits of achieving the number of pigs per sow as the top third producers***

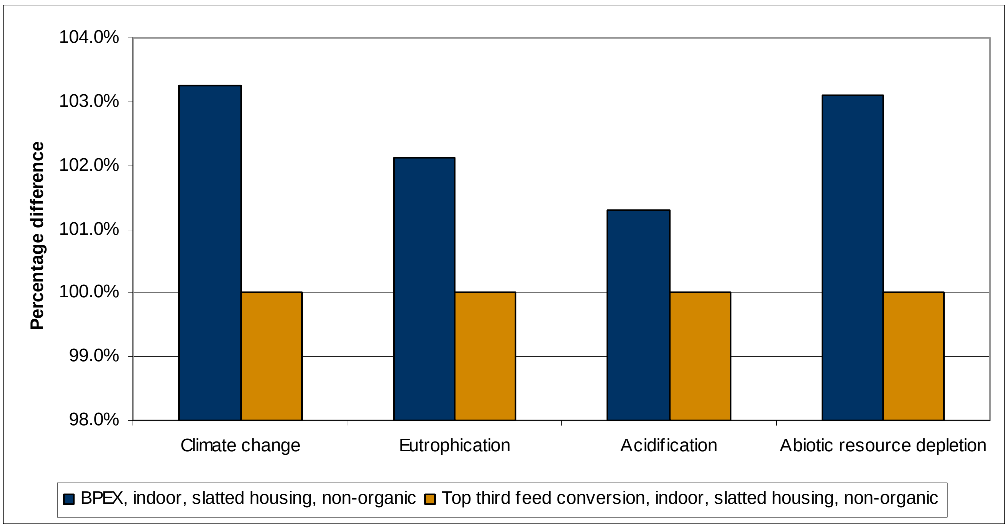


3.4.2 What if the feed conversion rates are the same as the top third?

In 2008, the top third of producers achieved average feed conversion rates of 1.51 for their weaning herds and 2.61 for their finishing herds compared to a British average of 1.74 and 2.87 respectively.

The benefits of achieving the feed conversion rates of the top third of producers are shown in *Figure 3.15* below. No other variables have been considered. The benefits achieved range from a 1.3% improvement in acidification to a 3.2% improvement in the climate change impact category.

Figure 3.15 ***Benefits of achieving the feed conversion ratios of the top third producers***

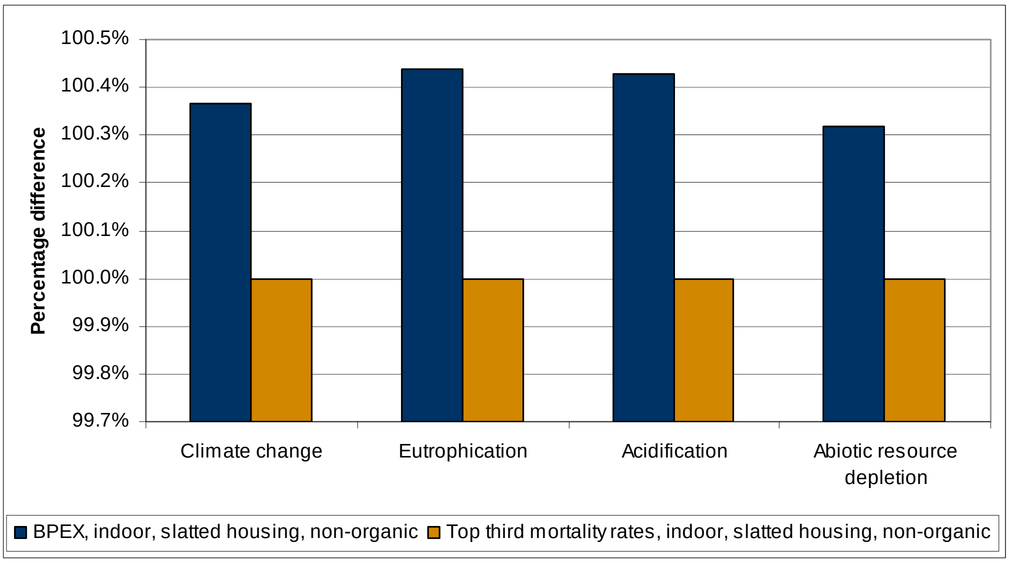


3.4.3 *What if the mortality is the same as the top third?*

In 2008, the top third producers achieve average mortality rates of 1.8% for their weaning herds and 3.0% for their finishing herds compared to a British average of 2.4% and 3.3% respectively.

The benefits of achieving the mortality rate of the top third producers for the weaning and finishing herds are shown in *Figure 3.16* below. The benefits achieved range from a 0.3% improvement in abiotic resource depletion to a 0.4% improvement in the other impacts.

Figure 3.16 Benefits of achieving the mortality rates of the top third producers

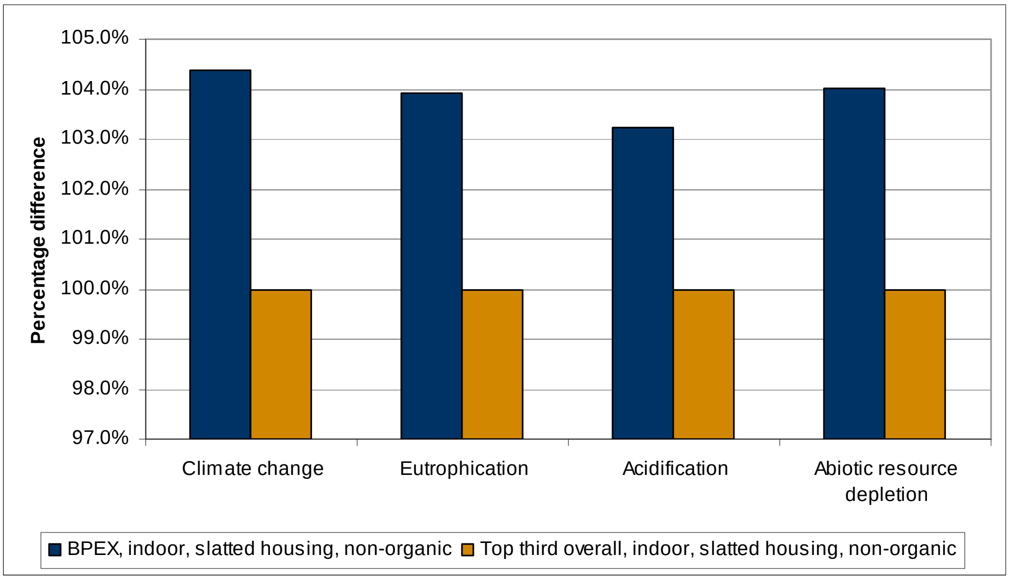


3.4.4 *Benchmarking of top third producers against British average*

In *Figure 3.17* below, the overall results for the top third of producers are compared to the average BPEX data for indoor bred pigs on slatted flooring.

The figure illustrates the combined benefits of achieving the piglet numbers, the feed conversion rates, and mortality rates of the top third of producers. The benefits achieved range from a 3.1% improvement in non-renewable energy consumption to a 4.2% improvement in contributions to climate change. The improvement achieved for the top third producers means that the climate change contributions from their pork, per kg pork product consumed, amounts to 8.3 kg CO_2 equivalents.

Figure 3.17 ***Benchmarking of top third producers against BPEX average***



3.4.5 What if the best housing type with regard to manure management were used?

The Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs lists ammonia emission factors for different housing types or systems.

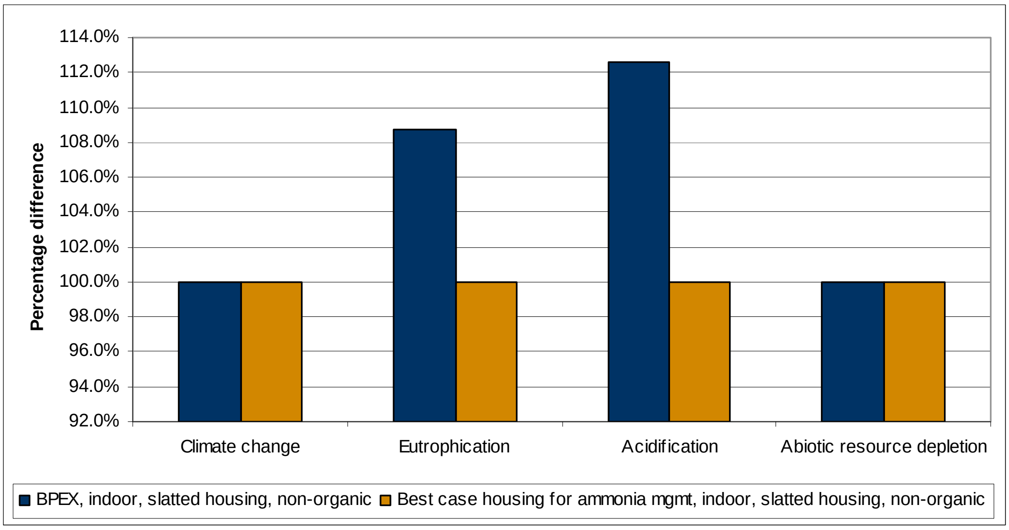
In order to illustrate the potential benefits to be achieved using alternative housing methods, the overall results for the average BPEX data for indoor bred pigs on slatted flooring as modelled in this study have been benchmarked against best case data as listed in the BREF document. The emission factors are listed in *Table 3.2* below.

Table 3.2 ***IPPC BREF emission factors used for comparison*** *(fully slatted flooring only)*

Pig	**Housing type/system**	**Emission factor reduction (%)**	**Emission factor (kg NH_3-N/animal place/year)**
Sows	Fully slatted floor with flush gutters / tubes and aeration	55%	1.35
Farrowing sows	Fully slatted floor and manure surface cooling fins	70%	0.90
Weaning pigs	Pens or flatdecks with fully slatted floor and flush gutters / tubes and aeration	50%	0.15
Finishing pigs	Fully slatted floor with flush gutters / tubes and aeration	70%	1.24

The potential benefits of incorporating the best case housing system for ammonia management are shown in *Figure 3.18* below. Benefits are only seen for eutrophication and acidification as ammonia does not contribute to climate change or cause abiotic resource depletion. The potential benefits are a 8.0% improvement in eutrophication and a 11.2% improvement acidification.

Figure 3.18 Benefits of best case housing system for ammonia management



4 DISCUSSION AND CONCLUSIONS

The overall aims of this study were threefold:

- to estimate the environmental impacts associated with pork products across their life cycle and to identify opportunities for improvement;
- to facilitate communication of the environmental impacts (in particular greenhouse gas emissions) with suppliers, and potentially with other stakeholders; and
- to inform decisions regarding any further data collection to validate secondary data used in this study and to improve the robustness of the model.

The modelling undertaken as part of this study has quantified the impacts of: climate change; eutrophication; acidification; and abiotic resource depletion associated with the production, processing, packaging and its disposal, and consumption of one kg of pork product. The findings can be summarised as follows.

- Pig production (comprising feed production, pig rearing, and slurry and manure management and spreading on land) is the life cycle phase that contributes the most to the environmental profile of pork products. For example, for pigs raised indoor on slatted flooring, pig production accounts for almost three quarters of the pork product's contribution to climate change (also often referred to as the carbon footprint).
- Of this, feed production is the element of pig production that makes the largest contribution. For example, the feed contributes 56% of the total carbon footprint of pork products from pigs raised indoor on slatted flooring.
- Storage in the home and preparation of the pork for consumption also contribute noticeably to the environmental profile of pork product. This is mainly in respect of the impact categories of climate change and abiotic resource depletion. These contributions are due to the energy consumed in the home for refrigerated storage of the pork and subsequent cooking.
- Transport and distribution throughout the life cycle, retail storage, packaging and its disposal at end of life account for between 1% and 11%, depending on the impact category considered. Distribution alone accounts for between 0.2% and 1.3%, depending on the impact category. The contribution to the environmental impacts of pork products from distribution, or other transport, retail storage and packaging, is therefore shown to be minimal.

Comparison of different pig farming methods has found that the farming methods of loose housing and outdoor breeding make a significantly higher contribution to eutrophication and acidification than pigs raised indoor on slatted flooring (as shown in *Table 4.1* below). A higher contribution is also seen for climate change, albeit that this is not so significant. The higher impact is almost solely a result of higher emissions from the housing unit and the application of manure to land, compared to slurry from indoor slatted flooring. The impacts of the management of the manure account for more than 180% of those of the slurry for all of impact categories assessed.

Table 4.1 Environmental profile of British pork production (1 kg consumed)

	Climate change	Eutrophication	Acidification	Abiotic resource depletion
	kg CO_2 eq	kg PO_4^{3-} eq	kg SO_2 eq	kg Sb eq
BPEX, indoor, fully slatted	8.6	0.057	0.19	0.053
BPEX, indoor, loose bedding	9.8	0.10	0.38	0.052
BPEX, outdoor bred, loose bedding	9.8	0.095	0.33	0.054

Outdoor manure is found to contribute less to climate change, eutrophication and acidification than slurry. However, since the outdoor farming method modelled as part of this study only considers outdoor breeding units, with the rearing and finishing herd assumed housed indoors on loose bedding, the total impacts across the pork product life cycle show this to have the second largest environmental profile of the farming methods assessed.

The BPEX data have been benchmarked with data provided by two producers of conventionally bred pigs (Producer A and B). This has shown that a number of general farming efficiency factors, as achieved by the two producers, can reduce the environmental profile of the pork product considerably. For example, Producer A and B achieve carbon footprints that are 7% and 11% lower respectively than those for average British pork products. The efficiencies include such measures as more pigs per litter achieved, lower feed conversion ratios, lower sow feed consumption, lower mortality and lower sow cull percentages. For Producer B, the use of liquid co-product as part of the finisher feed also contributes to a lowering of the environmental profile.

For Producer B, an additional reduction in the impact is also seen due to the anaerobic digestion of the slurry from the finishing herd before it is spread on land. Anaerobic digestion of slurry leads to significant savings with regard to climate change, eutrophication and acidification. This is due to the generation of electricity, and thereby the avoidance of electricity produced from fossil fuels. It should be highlighted that the anaerobic digestion model is based on a number of assumptions. Despite these uncertainties, the figure demonstrates the benefit of recovering the energy held in the slurry before its application to land.

Organic pork production has been benchmarked against the BPEX data for conventionally produced pork product. Organic pork production data were provided by an organic producer (Producer C). This exercise showed that, in the case of this particular producer, organic pork product has higher environmental impacts per kg product than the non-organic pork based on slatted flooring, but achieves lower impacts than the non-organic British pork product from loose housed or outdoor bred pigs. Without data from other organic pig farmers and further investigation of the underlying data provided by Producer C, it is difficult firmly to establish that organic pig farming has a lower environmental profile than conventional pig farming based on loose bedding.

In addition to the benchmarking exercise, "what if?" scenarios were developed and used to assess the environmental gains that could be achieved if the average British producer achieved the same performance results as the top third of producers, as presented in the Pig Year Book 2009. Such a raising of the bar would deliver benefits in the order of a 3.1% improvement in acidification, 3.8% improvement in eutrophication, 3.9% improvement in non-renewable energy consumption, and a 4.2% reduction in contributions to climate change.

In considering the potential for improving the environmental impacts of British pork products, the results show that the main improvements can be achieved in the pig farming phase of the pork product life cycle. Evaluating the results in further detail suggest that the measures for achieving the greatest improvements are:

1. utilising feed as efficiently as possible;
2. achieving higher numbers of pigs per litter; and
3. managing the slurry/manure in ways that reduce its impacts.

With regard to slurry management, in order to illustrate the potential benefits to be achieved using alternative housing methods, the overall results for the average BPEX data for indoor bred pigs on slatted flooring as modelled in this study were benchmarked against best case data as listed in the BREF document for Intensive Rearing of Poultry and Pigs. This showed the potential benefits delivered to be an 8.0% improvement in eutrophication and a 11.2% improvement acidification.

For the other life cycle stages, the results suggest that the potential for the greatest environmental improvements are as follows:

- Abattoir and meat processing:
  1. reducing electricity consumption;
  2. utilising heat more efficiently;
  3. manage emissions to water more effectively;

- Retail:
  1. optimise refrigeration of pork products in the regional distribution centre (RDC) and in store;

2. optimise transport from RDC to retail;

- Consumer use:
  1. minimise food waste; and
  2. install AA rated appliances (refrigerator and cooker).

In *Table 4.2* below, the climate change (carbon footprint), eutrophication and acidification results from this study are compared to the results of other studies for various European countries. No specific assessment has been done of the other studies, and it should be noted that the different studies have not used the same data and methods and therefore are not directly comparable. However, the studies measure a similar product, ie '1 kg pork (carcass weight) at farm gate'. This means that the processes beyond the farm gate are not included in this comparison.

The results from Halberg et al (2007) for organic pork production in Denmark are presented as a range, as three different organic production systems were studied. Similarly, the results for conventional pork production in this study could be presented as a range.

The results of this study are comparable to those of the Cranfield study (Williams et al, 2006). In part this is because the Cranfield study provided a major source for this study. The results of Dalgaard et al (2007), Cederberg & Flysjö (2004), and Basset Mens & van der Werf (2005) are comparable, but are also markedly lower than the results of this study. As pointed out in Dalgaard et al (2007), the reason for the higher results in the Cranfield study seems mainly to be due to:

- a different method being used for calculating nitrous oxides;
- higher ammonia emission per kg pig; and
- higher nitrate leaching during soya bean growth.

This suggests that an area for focusing further data collection, in order to validate the data used in this study, is the calculations of emission from pig housing and spreading on land, as well as the assumptions with regard to soya bean production.

In addition, it may be of interest to compare the different methods used in the various studies available in Europe on pork production in order to benchmark British pork products against those of other countries.

Table 4.2 *Comparison of pork production from different European LCA studies (per 1 kg pork (carcass weight) at farm gate)*

	Farming method	Climate change potential	Eutrophication potential	Acidification potential	Source
		kg CO_2 eq	g NO_3 eq	g SO_2 eq	
Current study					
Pork produced in UK	Indoor, slatted flooring	4.8	425	138	
Pork produced in UK	Indoor, loose bedding	5.7	780	289	
Pork produced in UK	Outdoor bred, loose bedding	5.7	715	249	
Pork produced in UK, Producer A	Indoor, slatted flooring	4.4	420	141	
Pork produced in UK, Producer B	Indoor, slatted flooring, liquid feed, anaerobic digestion	4.1	349	121	
Organic pork produced in UK, Producer C	Outdoor, loose bedding	5.4	660	199	
Other studies					
Pork produced in Great Britain		5.6	760	290	Cranfield study - Williams et al, 2006
Pork produced in Denmark		3.3	232	45	Dalgaard et al, 2007
Pork produced in Great Britain		3.4	301	61	Dalgaard et al, 2007
Organic pork produced in Denmark		3.8 - 4.3	353 - 501	67 - 81	Halberg et al, 2007
Pork produced in Sweden		2.6	170	37	Cederberg & Flysjö, 2004
Pork produced in France		3.0	274	57	Basset Mens & van der Werf, 2005

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