Environmental impact comparison of Post Weaning Mortality Syndrome trials

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Date: April 2019

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Glossary and Abbreviations

AgRE Calc©	- Agricultural Resource Efficiency Calculator (SRUC)
AME	- Apparent Metabolisable Energy
Carbon dioxide equivalent	- Where all gas emissions are expressed in terms of their relative GWP relative to carbon dioxide
CP	- Crude Protein
DD	- Digestibility
DE	- Digestible Energy
Direct emissions	- carbon equivalent emissions produced on the farm during the production process
Embedded emissions	- carbon equivalent emissions produced off the farm in the growing, production, processing and transport of products, inputs or livestock brought into the farming system
DDGS	- Distillers Dark Grains and Solubles
DLWG	- Daily LiveWeight Gain
DWT	- Deadweight
EA	- Environment Agency
Feed Print	- Dutch feed LCA database
GE	- Gross Energy
GHG	- Green House Gas
GWP	- Global Warming Potential
IPCC	- International Panel on Climate Change
LCA	- Life Cycle Analysis
LUC	- Land Use Change (associated with crop production)
LWT	- Liveweight
PAS2050	- British Standards Institute standard for Life Cycle Analysis
PWMS	- Post Weaning Mortality Syndrome
SAC	- SAC Consulting – a Division of SRUC
SRUC	- Scotland's Rural College
Tier 1	- LCA method using standard static emissions values per livestock unit
Tier 2	-LCA method using dynamic calculation of livestock emissions based on feed energy demand, feed intake, growth rate and related factors.

Executive Summary

1. SAC Consulting, a Division of SRUC, were commissioned by Devenish Nutrition, to prepare an environmental assessment of results generated and published in the peer-reviewed literature on PCV2 vaccination and control of Post Weaning Multisystemic Wasting Mortality Syndrome (PWMS)/Porcine Circovirus Associated Diseases (PCVADs).

2. The environmental indicators assessed were Greenhouse Gas (GHG) emissions and ammonia. They were calculated using SRUC's carbon and resource efficiency calculator; AgRE Calc© following Tier 2 methodologies, whereby the latter seeks to define livestock productivity, diet quality, feed intake in greater detail to support a more accurate estimate of feed intake for use in estimating methane and nitrous oxide production and to add ammonia emission estimates. SRUC also calculated ammonia emissions using a modified version of AgRE Calc©: Tier 2 A (ammonia).

3. GHG emissions were also compared with and without land use change (LUC) impacts on feed emissions, mainly from soyameal. The impacts of land use change in this study were taken to be due to the effects of converting land from forests or savannah into crop production, principally in South America. The main effects of LUC are seen in increased embedded carbon emissions from the use of soyameal however smaller impacts are also seen in the use of other feeds including; wheat, maize Distillers Dark Grains and Solubles (DDGS) rapeseed and vegetable oils.

4. Data was provided by Devenish Nutrition on; feed use, diet composition, mortality and livestock performance. Embedded emissions for the production of feed were derived from Feed Print 2015[1] and standard mill energy use figures provided by SAC. Energy use estimates were based on standard values from SAC Consulting.

5. The results showed that using a Tier 2 methodology not including LUC on a liveweight basis Trial 3: No Disease had the <u>lowest</u> carbon emissions per unit of output with the PWMS affected trials having emissions between 2% (Trial 2 Sub Clinical) and 10% (Trial 1 Clinical) higher on a liveweight basis. The better no Disease trial results are driven by greater Feed Conversion Efficiency due to higher DLWG and lower mortality.

[1] http://www.wur.nl/en/show/FeedPrint-Calculate-CO2-per-kilogram-meat-melk-or-eggs.htm

6. Using a more detailed Tier 2 A (ammonia) methodology incorporating recorded feed intake rather than calculated, not including LUC on a liveweight basis Trial 3 No Disease showed even lower absolute and relative emissions on a unit of output basis with the PWMS/PCVAD-affected trials having emissions between 13% (Trial 2 Sub Clinical) and 25% (Trial 1 Clinical) higher on a liveweight basis.

7. SRUC conducted estimates of ammonia emissions from both farms using a Tier 2 A (ammonia) AgRE Calc method to reflect changes in the composition of the feed. These were contrasted with Tier 1 methods (as used by the Environment Agency) where ammonia emissions remain static irrespective of the feed composition based as they are on animal numbers.

8. For the dominant category; Finishers, in the case of Trial 1 Clinical PWMS, the SRUC Tier 2 method predicts slightly higher ammonia emissions than the Tier 1 methods of the Environment Agency. The reason for this is the Tier 2 method fully accounts for the low FCR of the pigs. The Tier 2 emissions can be reduced for example by reducing the protein content of the feed, improving the feed conversion ratio or the general animal performance. The Tier 1 methods cannot account for such changes.

9. In the case of Trial 2 Pre-Clinical PWMS, for finishers the SRUC Tier 2 method predicts 12% lower ammonia emissions than the Tier 1 Environment Agency estimate and 49% lower for the Trial 3 No Disease. The reason for this is Tier 2 approach fully accounts for the improved FCR and lower mortality of Trials 2 and 3.

1.0 Objectives

This report, prepared by SAC Consulting, a Division of SRUC provides an environmental assessment of pig growing and finishing for a range of PWMS/PCVADS field observations trial result published in the peer-reviewed literature. The environmental indicators assessed were Greenhouse Gas (GHG) and ammonia emissions.

The overarching objective of the project is to assess the impact that PWMS/PCVAD and PCV2 vaccine use has on the environmental impact of pig production, using data supplied by Devenish Nutrition and Queen's University Belfast.

2.0 Methodology

<u>AgRE Calc©</u>

SRUC's Agricultural Resource Efficiency Calculator© (AgRE Calc©) was used to undertake the cradle to gate assessments. Cradle to gate is an assessment of a partial product life cycle from resource extraction (cradle) to the gate (i.e. the farm gate).

AgRE Calc© Tier 2 is certified to PAS 2050:2011[2] standards by approved verifier Lucideon, providing assurance that the GHG emissions being reported are calculated in a consistent way across the industry. PAS 2050 was developed by the British Standards Institution (BSI) in response to broad community and industry desire for a consistent method for assessing the life cycle GHG emissions of goods and services. It provides a common basis for GHG emission quantification that informs and enables meaningful GHG emission reduction programmes.

The AgRE Calc@ Tier 2 calculations follows the GHG emissions methodology published in the Intergovernmental Panel on Climate Change (IPCC). The Tier 2 methodology seeks to define livestock productivity, diet quality and management circumstances to support a more accurate estimate of feed intake for use in estimating methane and nitrous oxide production.

In order to calculate ammonia emissions a further version of AgRE Calc© was also used – Tier 2 A (ammonia). This requires additional detail on production systems and is not currently verified to PAS2050:2011.

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[2] http://shop.bsigroup.com/forms/PASs/PAS-2050-Guide/

Modules within AgRE Calc© were used to calculate emissions for the individual feed ingredients, based on figures from Feed Print 2015[3] and standard mill energy use figures provided by SACC. Further details of the relevant methodology used in AgRE Calc© Tier 2 are included in Appendix 1 and Tier 2 A (ammonia) in Section 5.

Table 1 – AgRE Calc© data requirement

Category	Tier 2	Tier 2 A (ammonia) Additional data
Livestock number and weight	Average livestock number and weight by life stage	
Sales, purchases and deaths	Number and weight of livestock bought, sold and, deaths by life stage, KO %	
Feed intake	Calculated feed intake per head by life stage	Recorded feed intake per head by life stage
Breeding	Number of litters per sow per year, number of piglets born and weaned per sow.	
Performance	Daily liveweight gain by growth stage	
Manures	Systems and whether exported	
Feed embedded emissions	Composition of feeds by ration, Feedprint GHG emissions per ingredient combined and standard SAC energy and transport emissions	
Feed quantities fed	Quantities fed by ration type and life stage	
Feed composition	Recorded Crude Protein, Digestibility, calculated Energy (AME)	Actual Energy (AME)
Energy use	Electricity, heat, red diesel and renewables	

[3] Feed Print 2015 - http://www.blonkconsultants.nl/wp-content/uploads/2016/06/Animal-products.pdf

Data

For calculating embedded feed emissions details of the quantities of each ingredient for every ration fed were supplied by Devenish Nutrition. SAC Consulting provided standard figures for energy use (mains gas and electricity) per tonne of feed processed in the feed mill and estimated local transport emission figures.

The data supplied was then used by SAC Consulting to calculate the relevant embedded GHG emission factors per tonne of feed.

For direct emissions on-farm data on;

- quantities of diets fed by stage (kg),
- feed composition,
- number of livestock purchased and sold by growth stage,
- number of deaths and mortality by growth stage
- opening and closing livestock weights (liveweight) at each stage and slaughter,
- kill out %

Devenish Nutrition provided data on;

- crude protein (CP) and Digestibility (%), gross energy (GE) and apparent metabolisable energy (AME) (MJ/kg DM) of the feed.

Feed quantities, ration information and calculated feed emissions factors are included in Appendix 2.

SAC Consulting supplied estimates of standard energy use for pig finishing farms.

Comparisons

Using AgRE Calc©, SAC Consulting calculated the Global warming potential expressed in kg CO_2e per kg liveweight (lwt) and deadweight (dwt) of pig-meat (net of purchase weight) following an IPCC methodology for Tier 2. Emissions are expressed on a net sales basis as embedded emissions associated with any purchased livestock were not included.

GHG emissions were compared with and without land use change (LUC) impacts. The impacts of land use change in this study were taken to be due to the effects of converting land from forests or savannah into crop production, principally in South America. The main effects of LUC are seen in increased embedded carbon emissions from the use of soyameal however smaller LUC impacts are also seen in the use of other feeds including wheat, maize Distillers Dark Grains and Solubles (DDGS) rapeseed and vegetable oils.

3.0 Data assessment

Before considering the results it is important to assess the input data from the farms in the study in order to understand differences in the results. Additional data on pig numbers and production is also detailed in Appendix 5.

Feed use and FCR

Feed use by stage for the three trials is detailed in the following table illustrating the high share of overall feed use concentrated in the finisher stage at between 80% (Trial 3) and 85% (Trial 1) of total feed use**.**

Table 2 – feed use by stage

Stage	**Feed quantities**			**Share of total diet**		
	Trial 1: Clinical (t)	Trial 2: SubClinical (t)	Trial 3: NoDisease (t)	Trial 1: Clinical (%)	Trial 2: SubClinical (%)	Trial 3: NoDisease (%)
Pig weaner feed	294	366	415	5%	5%	6%
Pig grower feed	660	802	948	11%	11%	14%
Pig finisher feed	5,005	6,104	5,482	84%	84%	80%
	5,959	**7,272**	**6,845**	**100%**	**100%**	**100%**

Feed efficiency and daily liveweight gain

Overall production efficiency for the rearing and finishing system was highest in Trial 3: No Disease where Feed Conversion Efficiency (FCR) (total feed use / total net pig-meat lwt produced) of 3.51 was 9.5% better than Trial 2 Sub Clinical and 14.4% better than Trial1 Clinical as shown in Table 3. As all three trial were fed the same diet this difference is due to better growth rates and lower mortality in the No Disease Trial.

Table 3 – Feed Conversion Ratio

	Trial 1: Clinical	Trial 2: SubClinical	Trial 3: NoDisease
Feed consumption (t)	5,959	7,272	6,845
Pig-meat production (t lwt)	1,453	1,873	1,952
FCR	4.10	3.88	3.51

Performance on a daily weight gain basis was strongest for Trial 3: No Disease which achieved the highest Daily LiveWeight Gain (DLWG) values at each stage, see Table 4. For the finisher stage, Trial 3 achieved a DLWG 37% higher than Trial 2 and 64% higher than Trial 1.

Table 4 – Growth rates

	Average daily weight gain		
	Trial 1: Clinical	Trial 2: SubClinical	Trial 3: NoDisease
Class/system	**(kg lwt/hd/d)**		
Finisher	0.725	0.868	1.188
Rearer	0.400	0.480	0.600
Weaner	0.250	0.330	0.400

Feed embedded emissions

Feed embedded emissions were calculated based on the composition of the diet ingredients and the estimated embedded carbon emission associated with each feed ingredient. Cereals dominated the diet at 74.5% with soyameal at 20.9% and other oils, proteins, amino acids and premix making up the remainder. All trials used the same feed.

The emissions factors were sourced predominantly from the Dutch feed industry environmental database; FeedPrint 2015. Table 5 illustrates the feed ingredients and the source of embedded emissions for the whole ration when considered without and including Land Use Change. Full details in Appendix 2, Table A1.

Table 5 - Feed ingredient and carbon emissions - whole ration average

	Share of diet	**Absolute emissions**		**Share of emissions**	
		No LUC	**LUC**	**No LUC**	**LUC**
	(%)	kg CO2e/t		(%)	
Cereals	74.5%	305	315	50%	24%
Soyameal	20.9%	134	840	22%	63%
Other oils, proteins	2.2%	48	49	8%	4%
Amino acids	0.1%	15	15	2%	1%
Premix, mins	2.4%	27	27	4%	2%
Processing		25	25	4%	2%
Transport to farm		54	54	9%	4%
	100.0%	**608**	**1325**	**100%**	**100%**

Embedded emissions for individual stage are detailed in Table 6. Higher emissions are seen in the weaner and grower feeds due to the use of higher embedded carbon emission feeds such as milk powder and soyameal and soyaoil. Given that finisher feed made up over 80% of the total rations the overall embodied carbon emissions of the feed were largely determined by the lower carbon ingredients used in that stage.

Table 6 – Embedded feed carbon emissions - finisher rations

	Feed embedded emissions	
	No LUC	**LUC**
		Kg cO2e/t
Pig weaner feed	1,500	2,346
Pig grower feed	618	1,243
Pig finisher feed	552	1,272
Ration average	**608**	**1,325**

4.0 GHG Results

Summary carbon emission results for the three trials are detailed below; full results are detailed in Appendix 3.

Emissions from pig-meat production

Carbon emissions for the three trials are shown in Table 7 below. Results are presented on both a liveweight and deadweight basis and with and without with consideration of Land Use Change (LUC). Results are presented for AgRE Calc Tier 2 and Tier 2 A (ammonia).

For AgRE Calc Tier 2 on a liveweight basis, no LUC, compared to No Disease (Trial 3) carbon emissions were higher in the other Trials by between +2% Sub Clinical (Trial 2) and +10% Clinical (Trial 1).

Table 7 a - Carbon emissions summary – Ag RE Calc Tier 2 - no LUC

AgRE Calc	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
Liveweight basis		kg CO2e /kg lwt	
Tier II - no LUC	**3.31**	**3.09**	**3.02**
Diff. compared to No Disease	0.29	0.07	
	10%	2%	
Deadweight basis		kg CO2e /kg dwt	
Tier II - no LUC	**4.26**	**4.01**	**3.92**
Diff. compared to No Disease	0.34	0.09	
	9%	2%	

Table 7 b - Carbon emissions summary – Ag RE Calc Tier 2 - LUC

AgRE Calc	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
Liveweight basis		kg CO2e /kg lwt	
Tier II – LUC	**5.59**	**5.24**	**4.95**
Diff. compared to No Disease	0.64	0.29	
	13%	6%	
Deadweight basis		kg CO2e /kg dwt	
Tier II – LUC	**7.20**	**6.79**	**6.43**
Diff. compared to No Disease	0.77	0.36	
	12%	6%	

For AgRE Calc Tier 2 A (ammonia) on a liveweight basis, no LUC, compared to No Disease (Trial 3) carbon emissions were higher in the other Trials by between +13% Sub Clinical (Trial 2) and +25% Clinical (Trial 1).

Table 8 a - Carbon emissions summary – Ag RE Calc Tier 2 A (ammonia) - no LUC

AgRE Calc	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
Liveweight basis		kg CO2e /kg lwt	
Tier II - no LUC	**3.37**	**3.04**	**2.70**
Diff. compared to No Disease	0.66	0.34	
	25%	13%	
Deadweight basis		kg CO2e /kg dwt	
Tier II - no LUC	**4.33**	**3.95**	**3.51**
Diff. compared to No Disease	0.82	0.44	
	23%	12%	

Table 8 b - Carbon emissions summary – Ag RE Calc Tier 2 A (ammonia) - LUC

AgRE Calc	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
Liveweight basis		kg CO2e /kg lwt	
Tier II – LUC	**5.65**	**5.18**	**4.63**
Diff. compared to No Disease	1.02	0.55	
	22%	12%	
Deadweight basis		kg CO2e /kg dwt	
Tier II – LUC	**7.27**	**6.72**	**6.01**
Diff. compared to No Disease	1.25	0.71	
	21%	12%	

Source of carbon emissions

Ag RE Calc© Tier 2 - The total level of carbon emissions by source on a per unit of output basis with no LUV are detailed in Table 9 (liveweight) and Table 11 (deadweight) below. The relative share of emissions by source is given in Table 10.

The dominant source of carbon emissions in all trials under no LUC scenarios is overwhelmingly from the embedded emissions associated with feed production. Excluding LUC feed represents between 55% (Trial 3) and 59% (Trial 2) of total emissions.

Table 9 – Carbon emissions per unit of output (liveweight) by source, AgRE Calc© Tier 2 no LUC

	kg CO2e /kg lwt		
	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
Energy use	0.65	0.51	0.42
Feed - no LUC	1.93	1.82	1.67
Carcasses	0.01	0.00	0.00
Methane – digestion	0.10	0.11	0.14
Methane - manure	0.48	0.52	0.64
Nitrous oxide – manures	0.13	0.13	0.16
Total - no LUC	**3.31**	**3.09**	**3.02**

Table 10 – Carbon emissions share by source (liveweight), AgRE Calc© Tier 2 no LUC

	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
Energy use	20%	17%	14%
Feed - no LUC	58%	59%	55%
Carcasses	0%	0%	0%
Methane – digestion	3%	4%	5%
Methane - manure	15%	17%	21%
Nitrous oxide – manures	4%	4%	5%
Total - no LUC	**100%**	**100%**	**100%**

Table 11 – Carbon emissions per unit of output (deadweight) by source, AgRE Calc© Tier 2 no LUC

	kg CO2e /kg dwt		
	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
Energy use	0.84	0.66	0.54
Feed - no LUC	2.49	2.36	2.17
Carcasses	0.02	0.01	0.00
Methane – digestion	0.13	0.14	0.18
Methane - manure	0.62	0.67	0.83
Nitrous oxide – manures	0.16	0.17	0.20
Total - no LUC	**4.26**	**4.01**	**3.92**

(Deadweight share of emissions as per liveweight - Table 10)

Methane from manures is the next largest source of carbon equivalent emissions at between 15% of emissions in Trial 1 Clinical and 21% in Trial 3 – no disease (excluding LUC). Energy is important and represents the highest share (20%) of carbon emissions (excluding LUC) in Trial 1. Nitrous oxide is a minor source of emissions at between 4% and 5% of total emissions for all trials (excluding LUC).

Ag RE Calc© Tier 2 A (ammonia) - The total level of carbon emissions by source on a per unit of output basis are detailed in Table 12 below. The relative share of emissions by source is given in Table 13.

The dominant source of carbon emissions in all trials under no LUC scenarios is even more associated with embedded emissions from feed production. Excluding LUC feed represents between 57% (Trial 1) and 62% (Trial 3) of total emissions.

Table 12 – Carbon emissions per unit of output by source, AgRE Calc© Tier 2 A (ammonia) no LUC

	kg CO2e /kg dwt		
	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
Energy use	0.84	0.66	0.54
Feed - no LUC	2.49	2.36	2.17
Carcasses	0.02	0.01	0.00
Methane – digestion	0.14	0.11	0.12
Methane - manure	0.67	0.63	0.57
Nitrous oxide – manures	0.18	0.15	0.10
Total - no LUC	**4.33**	**3.92**	**3.51**

Table 13 – Carbon emissions by source (%), AgRE Calc© Tier 2 A (ammonia) no LUC

	kg CO2e /kg dwt		
	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
Energy use	19%	17%	15%
Feed - no LUC	57%	60%	62%
Carcasses	0%	0%	0%
Methane – digestion	3%	3%	3%
Methane - manure	15%	16%	16%
Nitrous oxide – manures	4%	4%	3%
Total - no LUC	**100%**	**100%**	**100%**

Methane from manures is the next largest source of carbon equivalent emissions but at a lower level than in Tier 2 at between 15% of emissions in Trial 1 Clinical and 16% in Trial 3

– no disease (excluding LUC). Energy is important and represents the highest share (19%) of carbon emissions (excluding LUC) in Trial 1. Nitrous oxide is a minor source of emissions at between 3% and 4% of total emissions for all trials (excluding LUC). The use of recorded feed intake in the Tier A version leads to differences in emission estimates.

5.0 Ammonia methods and results

AgRE Calc© Tier 2A (ammonia) method for calculating ammonia emissions from pig farms

Rationale

For calculating ammonia emissions from livestock housing, IPCC Tier 1 emission factors are generally used (for example the Environmental Agency emission factors are based on the Tier 1 methodology). The Tier 1 method calculates the emissions based on the number of animals on the farm, or on the basis of the total weight of the animals (livestock units). Although some adjustment to these emission factors is possible, based on for example type of housing and feed composition, it is not possible to include changes in management in a detailed or accountable way in Tier 1 calculations. Factors that cannot be properly accounted for in this method include 1) feed composition, especially protein content, 2) observed feed consumption at different stages of production, and 3) animal performance. Here, SRUC have developed a new Tier 2 A method that can fully take into account all these factors in the calculations of housing ammonia emissions

Method

The AgRE Calc© livestock model is based on animal energy intake equations originally developed for the GLEAM livestock model. In its original version, the model predicts the feed intake based on calculated daily energy requirements for animal growth, maintenance, activity, lactation and pregnancy. Based on the calculated feed intake, the nitrogen intake is also calculated. The nitrogen retention is calculated based on the animal growth, and the nitrogen excretion is calculated as the difference between nitrogen intake and retention. The ammonia emissions are then calculated based on the amount of excreted nitrogen, using emissions factors specific for each production system. For the purpose of the Tier 2 A ammonia calculations, the energy intake model was adjusted so that it can take into account the actual observed feed intake (instead of calculations based on default parameters). In this method, the animal energy requirement is adjusted so that the calculated feed consumption matches the observed consumption. In this way, any changes in animal performance can be taken into account when the ammonia emissions are calculated.

Inputs needed

The standard AgRE Calc© input data are needed to allow the Tier 2 A ammonia emission calculations. In order to capture the actual farm performance in the emission estimate and to avoid any default values in calculations, the following inputs are especially important: 1) the number of animals produced, 2) the starting and finishing weight of animals in each category (sows, gilts, boars, piglets, weaners, rearers, finishers), 3) the age of animals at the start and end of each category, 4) mortality and other losses of animals in each category, 5) for sows, the number of piglets born per litter, and number of litters per sow per year, 6) description of the manure management system, 7) total consumption of feed in each category, 8) energy (ME) content of each phase feed, and 9) crude protein content of each phase feed.

Outputs

In the following, the calculated annual ammonia emissions for the three trials are shown. The estimates using other methods (for example Environmental Agency Tier 1 method) are shown for comparison. All units are kg ammonia per year.

Notes on methods in Table 14.

Method A: Preferred method; Tier 2 emissions from housing, based on excreted nitrogen and UK Ammonia Inventory Emission factors.

Method B: Tier 1 emissions from housing, based on the livestock units and UK Ammonia Inventory Emission factors.

Method C: Tier 1 emission from housing, based on annual animal places and Environmental Agency emission factors.

Method D: Tier 2 emissions from housing and storage, based on excreted nitrogen and IPCC emission factors.

Table 14 – Comparison of Ammonia Emissions estimates

Finisher	AgRE Calc Method A: Tier 2 (AI)	Env Agency Method B: Tier 1 (LU)	Method C: Tier 1 (AAP)	Method D: Tier 2 (IPCC)
		kg NH3 per animal place per year		
T1. Clinical	4.25	4.07	4.14	5.17
T2. Pre-Clinical	3.73	4.23	4.14	4.53
T3. No Disease	2.22	4.39	4.14	2.69
Difference compared to No Disease				
		kg NH3 per animal place per year		
T1. Clinical	2.04			
T2. Pre-Clinical	1.52			
T1. Clinical	92%			
T2. Pre-Clinical	69%			

The Tier 2 methods reflect changes in the composition of the feed, Tier 1 methods (as used by the Environment Agency) remain static irrespective of the feed composition based as they are on animal numbers. It can be seen that the magnitude of the estimated emissions is similar between most of the methods.

For the dominant category; Finishers, in the case of Trial 1 Clinical PWMS, the SRUC Tier 2 method predicts slightly higher ammonia emissions than the Tier 1 methods of the Environment Agency. The reason for this is the Tier 2 method fully accounts for the low FCR of the pigs. The Tier 2 emissions can be reduced for example by reducing the protein content of the feed, improving the feed conversion ratio or the general animal performance. The Tier 1 methods cannot account for such changes.

In the case of Trial 2 Pre-Clinical PWMS, for finishers the SRUC Tier 2 method predicts 12% lower ammonia emissions than the Tier 1 Environment Agency estimate and 49% lower for the Trial 3 No Disease. The reason for this is Tier 2 approach fully accounts for the improved FCR and lower mortality of Trials 2 and 3.

Appendix 1 - AgRE Calc© methodology relevant to project

Greenhouse gas emissions

Coefficients and methodology

The methodology employed is consistent with international and national standards including the Intergovernmental Panel on Climate Change (IPCC), the BSI standard for life cycle analysis (PAS 2050:2011), Carbon Trust (Footprint Expert) and Feed Print 2015. AgRE Calc© is certificated against PAS 2050:2011 and can use a Tier 1 and Tier 2 methodology when calculating emissions from livestock.

The Tier 2 methodology seeks to define livestock productivity, diet quality and management circumstances to support a more accurate estimate of feed intake for use in estimating methane and nitrous oxide production.

The Tier 2A (Ammonia) methodology collects greater detail particularly on the length of each life stage, the production at each stage and the composition of the diet.

Global warming potential (GWP) factors

All emissions figures are shown in kilograms of carbon dioxide equivalent (kgCO_2e) at the following average 100 year GWP conversion rates:

1 kg carbon dioxide is equal to 1 kgCO_2e

1 kg methane is equal to 25 kgCO_2e

1 kg nitrous oxide is equal to 298 kgCO_2e

These conversion rates are in line with PAS 2050 which requires that the latest GWP figures are used (currently 2007).

Project boundaries

All calculations included the upstream impacts of all major inputs (i.e. feeds) before arrival on the farm as well as all production processes on farm i.e. cradle to gate.

Carbon dioxide

Energy and other emissions involved in the production and manufacture of feeds and bedding were taken into account. Calculations were based on industry recognised coefficients for indirect energy inputs.

Source of CO_2	**Calculations**
Indirect energy use (feeds and bedding)	Quantities multiplied by standard emissions factors from Feed print 2015 and Footprint Expert v3.1

Nitrous oxide

Nitrous oxide emissions are released from manure management at storage. The approach for calculating nitrous oxide is based on IPCC guidelines.

Source of N_2O	**Calculations**
Managed manure (excreta and storage)	Tier 1 and 2 IPCC (2006) equations and emission factors

Methane

Methane is produced from the decomposition of manure under anaerobic conditions. Methane emissions from manure depend on the manure management systems on farms. The approach for calculating methane is based on IPCC guidelines.

Source of CH_4	**Calculations**
Manure management	Tier 1 and 2 IPCC (2006) equations and emission factors

Appendix 2 - Feed quantities, ration information and emissions

Table A1. Feed ration ingredients and embedded carbon emissions as share of total.

		No LUC		LUC	
	Share of diet (%)	Feed embedded carbon emissions **(kg CO2e/t)**	**Share of feed emissions (%)**	Feed embedded carbon emissions **(kg CO2e/t)**	**Share of feed emissions**
BARLEY	34%	409	23%	409	10%
WHEAT	39%	405	26%	431	13%
MAIZE	1%	614	1%	614	0%
Wheat Feed	0%	254	0%	254	0%
HI PRO SOYA	19%	641	20%	4414	62%
FULL FATT SOYA	2%	641	2%	641	1%
SOYA HULLS	0%	398	0%	398	0%
SOYA OIL	0%	1172	0%	1595	0%
Rapeseed ext	0%	481	0%	709	0%
Maize DDGS	0%	540	0%	540	0%
Sugar beet pulp	0%	366	0%	366	0%
LT FISH	0%	1355	0%	1355	0%
FISHMEAL	1%	1355	2%	1355	1%
MILK POWDER	1%	3346	5%	3346	2%
Limestone	0%	20	0%	20	0%
Mono DCP	0%	4999	0%	4999	0%
Salt	0%	180	0%	180	0%
Lysine	0%	8030	1%	8030	0%
Methionine	0%	5490	0%	5490	0%
Threonine	0%	16970	1%	16970	1%
Tryptophan	0%	9500	0%	9500	0%
PREMIX	2%	1143.8	4%	1143.8	2%
Processing		25	4%	25	2%
Transport to farm		54	9%	54	4%
	100%		**100%**		**100%**
		kg CO2e/t		kg CO2e/t	
Ration weighted average		**607.79**		**1325.26**	

Table A2. Feed ration analysis information

All farms	Digestibility of the diet (%)	Crude protein in diet (%)	AME from feed (MJ/kg DM)
Finisher (i.e. >66kg)	86.97	17.00	14.42
Grower (i.e. 32-66kg)	86.95	18.00	14.66
Weaner (i.e. 14-31kg)	86.95	18.00	14.66
Weaner (i.e. 7-13kg)	91.41	20.00	16.13
Average	**88.07**	**18.25**	**14.97**

Table A3 – Feed ration quantities by age class

Feed quantities by stage

Stage	Feed quantities			Share of diet		
	T1: Clinical (t)	T2: SubClinical (t)	T3: NoDisease (t)	T1: Clinical (%)	T2: SubClinical (%)	T3: NoDisease (%)
Pig weaner feed	294	366	415	5%	5%	6%
Pig grower feed	660	802	948	11%	11%	14%
Pig finisher feed	5,005	6,104	5,482	84%	84%	80%
	5,959	**7,272**	**6,845**	**100%**	**100%**	**100%**

Appendix 3 - Carbon emission results

Table A4. Carbon emissions AgRE Calc©, Tier 2

IPCC	AgRE Calc V1.4 Tier II	No LUC		LUC		
Devenish PWMS						
0	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
	Pigs kg CO2e	**Pigs** kg CO2e	**Pigs** kg CO2e	**Pigs** kg CO2e	**Pigs** kg CO2e	**Pigs** kg CO2e
Diesel [1]	762,436	772,472	624,615	762,436	772,472	624,615
Electricity [1]	11,212	11,412	10,051	11,212	11,412	10,051
Other fuels [1]	448,833	459,324	425,814	448,833	459,324	425,814
Renewable electricity [1]	-	-	-	-	-	-
Renewable heat [1]	-	-	-	-	-	-
Direct CO_2	**1,222,481**	**1,243,209**	**1,060,480**	**1,222,481**	**1,243,209**	**1,060,480**
Fertiliser	-	-	-	-	-	-
Lime	-	-	-	-	-	-
Feed	3,613,313	4,416,079	4,236,317	7,877,164	9,620,668	9,125,793
Bedding	-	-	-	-	-	-
Pesticides	-	-	-	-	-	-
Waste plastic / packaging	-	-	-	-	-	-
Refrigerant losses	-	-	-	-	-	-
Disposal of carcasses	27,626	10,017	6,063	27,626	10,017	6,063
Transport	-	-	-	-	-	-
Indirect CO_2	**3,640,938**	**4,426,096**	**4,242,380**	**7,904,790**	**9,630,685**	**9,131,855**
Total CO_2 from energy use	**4,863,419**	**5,669,305**	**5,302,860**	**9,127,270**	**10,873,893**	**10,192,335**
Fermentation (feed digestion)	193,154	268,806	345,327	193,154	268,806	345,327
Manure management	898,184	1,253,133	1,612,837	898,184	1,253,133	1,612,837
Total CO_{2e} from methane	**1,091,337**	**1,521,939**	**1,958,164**	**1,091,337**	**1,521,939**	**1,958,164**
Inorganic fertiliser and imported organic manure input to soil	-	-	-	-	-	-
Grazing deposition, manure management and organic manure input to soil	239,044	323,982	398,625	239,044	323,982	398,625
Crop N residues	-	-	-	-	-	-
Total CO_{2e} from nitrous oxide	**239,044**	**323,982**	**398,625**	**239,044**	**323,982**	**398,625**
kg CO_2e	**6,193,801**	**7,515,225**	**7,659,649**	**10,457,652**	**12,719,814**	**12,549,124**
total kg CO_2e	6,193,801	7,515,225	7,659,649	10,457,652	12,719,814	12,549,124
kg CO_2e / kg lwt	**3.31**	**3.09**	**3.02**	**5.59**	**5.24**	**4.95**
kg CO_2e / kg dwt	**4.26**	**4.01**	**3.92**	**7.20**	**6.79**	**6.43**
kg [2]	**1,453,125**	**1,872,958**	**1,952,375**	**1,453,125**	**1,872,958**	**1,952,375**

Table A5. Carbon emissions – AgRE Calc©, Tier 2 A (ammonia)

IPCC	AgRE Calc V1.5 Ammonia Tier II A (ammonia)	No LUC		AgRE Calc V1.5 Ammonia Tier II A (ammonia)	LUC	
Devenish PWMS	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease	Trial 1 - Clinical	Trial 2 - Sub Clinical	Trial 3 - No Disease
	Pigs kg CO2e	**Pigs** kg CO2e	**Pigs** kg CO2e	**Pigs** kg CO2e	**Pigs** kg CO2e	**Pigs** kg CO2e
Diesel (1)	762,436	772,472	624,615	762,436	772,472	624,615
Electricity (1)	11,212	11,412	10,051	11,212	11,412	10,051
Other fuels (1)	448,833	459,324	425,814	448,833	459,324	425,814
Renewable electricity (1)	-	-	-	-	-	-
Renewable heat (1)	-	-	-	-	-	-
Direct CO2	**1,222,480**	**1,243,209**	**1,060,480**	**1,222,480**	**1,243,209**	**1,060,480**
Fertiliser	-	-	-	-	-	-
Lime	-	-	-	-	-	-
Feed	3,613,313	4,416,079	4,236,317	7,877,164	9,620,668	9,125,793
Bedding	-	-	-	-	-	-
Pesticides	-	-	-	-	-	-
Waste plastic / packaging	-	-	-	-	-	-
Refrigerant losses	-	-	-	-	-	-
Disposal of carcasses	27,460	9,971	6,038	27,460	9,971	6,038
Transport	-	-	-	-	-	-
Indirect CO2	**3,640,773**	**4,426,051**	**4,242,355**	**7,904,624**	**9,630,639**	**9,131,831**
Total CO2 from energy use	**4,863,253**	**5,669,259**	**5,302,835**	**9,127,104**	**10,873,848**	**10,192,310**
Fermentation (feed digestion)	206,004	251,434	237,231	206,004	251,434	237,231
Manure management	966,691	1,179,519	1,109,746	966,691	1,179,519	1,109,746
Total CO2e from methane	**1,172,694**	**1,430,953**	**1,346,978**	**1,172,694**	**1,430,953**	**1,346,978**
Inorganic fertiliser and imported organic manure input to soil	-	-	-	-	-	-
Grazing deposition, manure management and organic manure input to soil	259,361	290,159	202,954	259,361	290,159	202,954
Crop N residues	-	-	-	-	-	-
Total CO2e from nitrous oxide	**259,361**	**290,159**	**202,954**	**259,361**	**290,159**	**202,954**
kg CO2e	**6,295,309**	**7,390,371**	**6,852,766**	**10,559,160**	**12,594,960**	**11,742,242**
total kg CO2e	6,295,309	7,390,371	6,852,766	10,559,160	12,594,960	11,742,242
kg CO2e / kg lwt	**3.37**	**3.04**	**2.70**	**5.65**	**5.18**	**4.63**
kg CO2e / kg dwt	**4.33**	**3.95**	**3.51**	**7.27**	**6.72**	**6.01**
kg (2)	**1,453,125**	**1,872,958**	**1,952,375**	**1,453,125**		**1,952,375**

Appendix 4 - Ammonia emission results

Table A6 – Ammonia results - AgRE Calc©, Tier 2 A

PWMS T1. Clinical
Nitrogen excretion (kg N)

	AgRE Calc Nitrogen excretion rates (kgN/hd/yr)	Total nitrogen excretion (kg N)
Finisher	17.03	104,092
Grower	7.19	14,382
Weaner	2.11	4,604

PWMS T1. Clinical
Ammonia emissions (kg NH3) per farm

	AgRE Calc	Env Agency		
	Method A: Tier 2 (AI)	**Method B: Tier 1 (LU)**	**Method C: Tier 1 (AAP)**	**Method D: Tier 2 (IPCC)**
	AgRE Calc	Env Agency		
Finisher	26,013	24,901	25,312	31,600
Grower	3,594	2,621	3,181	4,366
Weaner	309	604	634	1,398
Total	**29,916**	**28,125**	**29,126**	**37,363**

PWMS T2. Pre-Clinical
Nitrogen excretion (kg N)

	AgRE Calc Nitrogen excretion rates (kgN/hd/yr)	Total nitrogen excretion (kg N)
Finisher	14.94	115,215
Grower	7.94	16,973
Weaner	2.52	5,505

PWMS T2. Pre-Clinical
Ammonia emissions (kg NH3) per farm

	AgRE Calc	Env Agency		
	Method A: Tier 2 (AI)	**Method B: Tier 1 (LU)**	**Method C: Tier 1 (AAP)**	**Method D: Tier 2 (IPCC)**
Finisher	28,792	32,604	31,934	34,976
Grower	4,242	3,256	3,400	5,153
Weaner	370	664	634	1,671
Total	**33,404**	**36,524**	**35,968**	**41,800**

PWMS T3. No Disease
Nitrogen excretion (kg N)

	AgRE Calc Nitrogen excretion rates (kgN/hd/yr)	Total nitrogen excretion (kg N)
Finisher	8.86	71,223
Grower	8.92	19,295
Weaner	2.65	5,792

PWMS T3. No Disease
Ammonia emissions (kg NH3) per farm

	AgRE Calc	Env Agency		
	Method A: Tier 2 (AI)	**Method B: Tier 1 (LU)**	**Method C: Tier 1 (AAP)**	**Method D: Tier 2 (IPCC)**
Finisher	17,799	35,267	33,265	21,621
Grower	4,822	3,794	3,441	5,857
Weaner	389	717	634	1,758
Total	**23,009**	**39,778**	**37,340**	**29,237**

Appendix 5 – Pig numbers and production data

Table A7 – Pig numbers and production

	Average number of livestock over 12 month period (no)	Days on Farm	Average weight (kg lwt)	Sales (head)	Average Weight sold (kg dwt)	Net weight sold (kg lwt)	Net weight sold (kg dwt)
Trial 1. Clinical							
Finisher	6,114	105	102.4	20,514	102.40	1,453,125	1,869,784
Grower	2,000	28	26.3				
Weaner	2,186	28	15.1				
Trial 2. Sub Clinical							
Finisher	7,714	83	102.79	25,882	102.79	1,872,958	2,429,561
Grower	2,138	28	30.78				
Weaner	2,186	28	17.34				
Trial 3. No Disease							
Finisher	8,035	56	102.6	26,962	102.60	1,952,375	2,535,451
Grower	2,164	28	36.1				
Weaner	2,186	28	19.3				