Australian Government
Department of Agriculture

AUSTRALIAN Pork™

PigGas – Pork Industry Greenhouse Gas Calculator and Case Studies

Final Report
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1. Acknowledgements

This project is supported by funding from Australian Pork Limited and the Department of Agriculture.

The project team acknowledges the case study piggery owners and managers - Ian Connaughton, Sally Walker, Andree Rowntree, Jamie Anderson, Ken Cameron, Alan Hudson, Steven and Kim Roberts, Peter and Kim Munro and Matthew Simmons for permitting access to and use of production, waste management and energy data for use in the case studies and for trialling the PigGas Calculator.

Alan Skerman and Sarah Willis provided standard dietary ingredients and growth data from PigBal Version 2013, currently under development, for inclusion in the PigGas Calculator to ensure commonality.

2. Executive Summary

This project was undertaken to provide the Australian Pork industry with a farmer-friendly calculator that could be used to determine the greenhouse gas emissions (Scopes 1 and 2) from individual piggery enterprises.

Even though agricultural enterprises are not included in Australia's Carbon Pricing Mechanism, the Australian Government is encouraging agricultural industries to find ways to reduce their greenhouse gas emission voluntarily.

The Pork Industry Greenhouse Gas (PigGas) Calculator developed in this project is aimed at providing pork producers with a tool to calculate their piggery enterprise emissions and identify ways in which to reduce them.

PigGas Calculator is a useful extension tool which models the emissions from any piggery production and waste system combination using the methodology and calculation protocols developed by the Australian Government for its international reporting obligations.

PigGas Calculator is a graphical spreadsheet calculator programmed in *Microsoft Excel 2010*. This was chosen because most pork producers and their advisors have access to this software on their home and business computers. The outline of the calculator methodology is presented in Appendix 1.

PigGas Calculator has been field tested and fine-tuned on six case study piggeries with widely varying production types, sizes, feed efficiencies and waste management systems.

The summaries of these six case studies are presented in Appendix 2. Total on-farm greenhouse gas emissions and emissions intensity were calculated. Emissions ranged from 39.2 tonnes CO_2-e /yr with an emissions intensity of 1.21 kg CO_2-e / kg HSCW for a 48 sow free range farrow to pork piggery up to 12,550 tonnes CO_2-e/yr and 6.39 kg CO_2-e / kg HSCW for a large conventional farrow to finish piggery with anaerobic lagoon waste treatment system.

For each farm, it was possible to model potential emissions reductions. The smallest improvement was a 5% reduction in emissions from a small, very low emissions piggery (outdoor bred, deep litter grown) which replaced on-site electricity usage with solar power. The largest on-farm emissions

intensity reduction of 87% was from a large conventional piggery covering its anaerobic treatment lagoon to minimise methane emissions, and combusting the captured methane to generate electricity and heat to replace on-site energy usage.

3. Background to Research

The Australian Government has implemented a Carbon Pricing Mechanism for industry enterprises emitting more than 25,000 tonnes of carbon dioxide equivalents in a financial year per year. Most farming enterprises including piggeries fall under this threshold, and agriculture is not yet included in the Mechanism. However, the Australian Government is encouraging agriculture to find ways to reduce its net emissions (Department of Climate Change and Energy Efficiency, 2012a).

Regardless of whether agriculture may be included in the future, the government's aim is to ensure that the agricultural sector makes a contribution to reduce its greenhouse gas emissions which currently account for about 15.5% of Australia's total emissions, with piggeries accounting for about 0.4% of the total.

Voluntary emissions trading is currently possible and the government may provide future financial incentives to trade voluntarily and/or regulate to achieve agricultural sector reductions. The Carbon Farming Initiative is one method which was implemented in 2012, with the first methodology developed being the 'Destruction of methane generated from manure in piggeries' using covered anaerobic lagoons and methane combustion (Department of Climate Change & Energy Efficiency 2011a).

The Australian Pork Industry is currently in the process of studying its emissions profiles and filling gaps in knowledge with Life Cycle Assessments and research to quantify on-farm emissions. However, an extension process needs to run concurrently if the pork industry is to succeed in quantifying emissions at the individual enterprise level.

This project has provided the pork industry with an extension tool (PigGas Calculator) needed to make on-farm decisions, together with six broad piggery case studies to examine the range of possible greenhouse gas emissions and options for on-site mitigation.

4. Objectives of the Research Project

1. Develop Pork Industry Greenhouse Gas (PigGas) Calculator – a graphical spreadsheet model for piggeries based on the Australian methodology for estimating greenhouse gas emissions modified to incorporate individual piggery production and waste management information.
2. Complete six case studies of piggery emissions using the PigGas Calculator which encompass the range of possible piggery types and emission types for Australian piggeries.

5. Introductory Technical Information

The Federal Department of Climate Change and Energy Efficiency has developed greenhouse gas accounting and reporting tools for industry including piggeries (Department of Climate Change & Energy Efficiency 2011b, 2012b).

These methods were followed in the development of PigGas. In some calculations, however, the methods, which were developed to represent industry at a state or national level using state

statistics, are not suitable for use at the individual piggery level. For example, state-level estimates (percentages) are used to apportion waste to a range of 'manure management systems', but can totally misrepresent the systems used in the individual piggery. Further, the Methodology defines only four pig classes (boars, sows, gilts and 'other pigs'). These classes align with national herd statistics reported by the Bureau of Statistics and suit the reporting of greenhouse gas emissions at the state or national level. However, the restriction to four classes does not allow the fine tuning of diets, feed efficiencies or waste systems for each pig category or individual group of pigs on each farm.

PigGas overcomes these and other deficiencies by providing the typical range of pig classes and waste systems. It allows for site-specific piggery analyses using unique stock and dietary information together with growth rate data and waste treatment categorization and reuse methods for each individual group of pigs on-farm.

Refer to Appendix 1 for a detailed outline of PigGas methodology and the references used.

6. Research Methodology

The PigGas Calculator was programmed to model greenhouse gas emissions according to the methodology used by the Department of Climate Change and Energy Efficiency in the estimation of Australia's National Greenhouse Gas Accounts. In addition, the PigGas Calculator enables the input of user-defined data in the event that site-specific or industry-researched data may be permitted to be used in lieu of DCCEE protocols in future.

Data from six case study farms were used to develop and validate the PigGas Calculator and to provide some insight into potential future energy reduction, emissions reduction and trading options for the pork industry. The case studies provided valuable extension information.

Six piggery owners and their managers agreed to provide farm data and assist trialling the PigGas Calculator. These piggeries represent a range of production, housing and waste management types as follows:

- 1,070 sow farrow to finish conventional piggery, flushed drains, sedimentation and evaporation ponds, and anaerobic ponds, South West Slopes NSW.
- 28,030 pig wean to finish conventional piggery, flushed drains, run down screens, covered anaerobic pond with methane flaring, Central Vic.
- 13,700 weaner piggery, deep litter (straw), South East Qld.
- 154 sow farrow to finish conventional pit storage piggery and large facultative pond, Central West NSW.
- 125 sow outdoor bred, indoor wean to finish piggery on deep litter (straw), drafting and holding sheds with slurry tanks, South West Slopes NSW.
- 48 sow farrow to pork free range piggery, Sydney Basin NSW

The PigGas Calculator was developed in *Microsoft Excel 2010*. This software was chosen because most pork producers and their advisors have access to this program on their home and business computers. The PigGas Calculator was trialled with each piggery owner/manager to test the robustness of the program, fine-tune to user requirements and provide emissions profiles for each piggery.

7. Discussion of Results

7.1 PigGas Calculator – Graphical Spreadsheet Model

Appendix 1 provides an outline of the PigGas Calculator Methodology, Contents and User Guide. This is presented in a form to be published separately as a 'Technote'.

7.2 Six Piggery Greenhouse Gas Emission Case Studies

PigGas Calculator has been field tested and fine-tuned on six case study piggeries with widely varying production types, sizes, feed efficiencies and waste management systems.

Appendix 2 details case studies of the emissions profiles of the six chosen piggeries and potential options to reduce on-farm emissions at each site. These case studies are presented in the form of 'Technotes' for website and print publication by Australian Pork Limited and NSW Department of Primary Industries.

Scope 1 and Scope 2 greenhouse gas emissions are calculated (carbon footprint) at the individual property/business enterprise level. Estimates of Pre-farm and Post-farm emissions can also be entered manually into PigGas from other sources to obtain an estimate of the Life Cycle Emissions of a pig production.

The summaries of these six case studies are presented in Appendix 2. Total on-farm greenhouse gas emissions and emissions intensity were calculated. Emissions ranged from 39.2 tonnes CO_2-e /yr, with emissions intensity of 1.21 kg CO_2-e / kg HSCW for a 48 sow free range farrow to pork piggery, up to 12,550 tonnes CO_2-e/yr, with 6.39 kg CO_2-e / kg HSCW for a large conventional farrow to finish piggery with anaerobic lagoon waste treatment system.

PigGas was used to identify possible strategies to reduce or offset emissions on each farm. Possible strategies include covering lagoons, separating solids, increasing feed efficiency, improving pig production, changing production systems, changing waste treatment system, offsetting energy usage with green power, changing soil application methods and exporting solids and effluent.

For each farm, it was possible to model potential emissions reductions. The smallest on-farm emissions intensity reduction of 5% was from a small, low emissions piggery (outdoor bred, deep litter grown) which replaced on-site electricity usage with solar power. The largest on-farm emissions reduction of 87% was from a large conventional piggery covering its anaerobic treatment lagoon to minimise methane emissions, and combusting the captured methane to generate electricity and heat to replace on-site energy usage.

8. Implications & Recommendations

This project adds value to APL's whole-of-chain Life Cycle Assessment projects and on-farm Greenhouse gas emissions research program.

PigGas Calculator allows individual piggery owners and managers to calculate on-farm emissions using the Australian Methodology for greenhouse gas accounting and apply 'what-if' scenarios to identify possible mitigation strategies. This may assist those looking to voluntarily trade on their emissions reductions through the Carbon Farming Initiative or other future voluntary or mandatory scheme. It will allow individual piggeries to benchmark their emissions profile against other piggeries and other farming enterprises. This may have marketing implications in the future.

8.1 Options for Extension

The 'PigGas Calculator' software will be published on both APL and NSW DPI websites for free downloading.

The 'PigGas Calculator – Methodology, Contents and User Guide', together with the six piggery 'Case Studies', written as 'Technotes', will be published on the Australian Pork Limited and NSW Department of Primary Industries websites and may also be published in print form for industry distribution.

Information about the PigGas Calculator and results of the case studies will be published as articles in the Australian pork press and relevant conferences.

8.2 Suggestions for Workshops

Interstate workshop series may be held, subject to funding, either with APL Road shows, or preferably, as a stand-alone future program.

A suggested half-day *'PigGas Workshop'* outline is as follows:

- Brief description of the Australian methodology for estimating piggery greenhouse gas emissions.
- Overview of the PigGas Calculator methodology.
- Summary of PigGas case study results to date and potential uses.
- Piggery production input data needed for running PigGas.
- Demonstration of PigGas inputs, calculations and reports.
- Distribution of PigGas software and user guide.
- Brief problem solving follow up with individual producers as needed post-workshop.

9. Intellectual Property

The aim of the project was to make an emissions calculation tool widely and freely available to all sectors of the pork industry to enable a better understanding of piggery greenhouse gas emissions and potential means to reduce those emissions or provide emission offsets.

The PigGas Calculator will be made available for download from the websites of both Australian Pork Limited and NSW Department of Primary Industries. Information relating to the PigGas Calculator and the case studies resulting from the project will be published, widely disseminated and promoted, with training and extension provided as necessary.

10. Technical Summary

See Appendices 1 and 2 and the attached PigGas Calculator spreadsheet software.

11. References

Department of Climate Change and Energy Efficiency (2011a) Carbon Farming Initiative: Methodology for the destruction of methane generated from manure in piggeries. Approved by Domestic Offsets Integrity Committee, September 2011. http://www.climatechange.gov.au/government/submissions/closed-consultations/carbon-farming-initiative/~/media/government/initiatives/cfi/methodology-development/methodologies-under-consideration/CFI-MethanePiggeriesMethodology-20111205-PDF.pdf

Department of Climate Change and Energy Efficiency (2011b) National Greenhouse Accounts Factors. Department of Climate Change and Energy Efficiency, Commonwealth of Australia, Canberra ACT, July 2011. ISBN: 978-1-921299-86-5

Department of Climate Change (2012a) *Clean energy legislation: the way ahead.* http://www.climatechange.gov.au/government/clean-energy-future.aspx

Department of Climate Change and Energy Efficiency (2012b) Australian National Greenhouse Accounts - National Inventory Report 2010 Volume 1. The Australian Government Submission to the UN Framework Convention on Climate Change April 2012. Department of Climate Change and Energy Efficiency, Commonwealth of Australia, Canberra ACT, April 2012. ISBN: 978-1-922003-28-7.

12. Publications Arising (to Date)

Kruger, I, Mills, G and Madden, P. (2011) Pork Industry Greenhouse Gas (PigGas) Calculator. Abstract and Poster paper in Climate '11 – Impacts and Adaptations. Climate Symposium, Wagga Wagga, June 2011. NSW Department of Primary Industries.

Appendix 1 - PigGas Methodology, Contents & User Guide

Summary

The **PigGas** Calculator (**P**ork **I**ndustry **G**reenhouse **Gas** Calculator) was developed to provide pork producers and advisers with a tool to estimate carbon dioxide equivalent emissions within the boundary of the piggery enterprise.

It provides a measure of the piggery enterprise Scope 1 and Scope 2 emissions over which the pig farmer has some immediate control. Scope 1 or direct emissions are a direct result of the piggery activities and on-site combustion of fuels. Scope 2 or indirect emissions result from consumption of electricity purchased off-site.

PigGas also provides an estimate of the major Scope 3 or 'lifecycle' emissions in the broader upstream or downstream supply chain outside the enterprise boundary e.g., growing of grains, milling of purchased feedstuffs, off-site transport of feeds and straw, off-site pig transport and meat processing.

PigGas provides flexibility to input farm-specific data and production characteristics. While it closely follows the Australian methodology for estimating greenhouse gas emissions from piggeries (Department of Climate Change and Energy Efficiency 2011a and Department of Climate Change and Energy Efficiency, 2012), it provides the capacity to fine-tune production activities and the resulting emissions at the individual piggery enterprise level.

Users can perform 'what-if' scenarios by making changes to energy, pig groups, feedstuffs, growth performance, indoor and outdoor production systems, waste management systems, solids separation, soil application methods, manure exports and emissions offsets to find ways to reduce pig enterprise greenhouse gas emissions.

Reports can be printed which show the piggery emissions profiles (source, quantities and totals).

PigGas is freely available and can be downloaded as a *Microsoft Excel 2010* file from the websites of Australian Pork Limited and the NSW Department of Primary Industries.

Brief Background to Australia's Carbon Accounting System

Greenhouse gas emissions from piggeries are categorized as direct or indirect emissions Australian Pork Limited (2008). Direct emissions (Scope 1) are from sources that are owned or controlled by the piggery enterprise. Indirect emissions (Scopes 2 or 3) are emissions that result from activities associated with pork production, but occur at sources owned or controlled by another entity. For piggeries, Scope 2 indirect emissions result from consumption of purchased electricity. For piggeries, Scope 3 indirect emissions result from any upstream or downstream products or services purchased or used by the business to produce or market the pig products e.g., manufacture of purchased feedstuffs, piggery supplies, off-site pig transport or processing.

In 2002, emissions from piggeries or pork production (Scopes 1 & 2) comprised only 0.4% of Australia's net national emissions (DCC, 2008). In comparison, beef cattle emitted 11.2%, sheep 3.4%, dairy cattle 2.7%, grains 1.1%, poultry 0.3%, sugar cane 0.2% and cotton 0.1%. In 2009, agriculture emitted approximately 84.7 Mt CO_2-e or 15.5% of Australia's net national emissions (Department of Climate Change and Energy Efficiency, 2011a).

The National Greenhouse Accounts for agriculture (Department of Climate Change and Energy Efficiency, 2011a) incorporates Scope 1 calculations for enteric fermentation, manure management, rice cultivation, agricultural soils, prescribed burning of Savannas and field burning of agricultural residues. For any agricultural enterprise, the relevant default emissions calculations from this suite are combined with Scope 1 on-site fuel combustion emissions plus Scope 2 purchased electricity emissions to give an estimate of total enterprise boundary emissions (carbon footprint).

Where Does PigGas Fit?

The publication titled 'National Greenhouse Account Factors, July 2011' (DCCEE 2011a) in 'Section 5.3 Estimating agricultural emissions, states the following:

> *State and national-level estimates of greenhouse gas emissions from agriculture are prepared using the methodology set out in the National Inventory Report 2009.*
> *Organisations wishing to report emissions from their agricultural operations may draw on this national methodology to make indicative estimates, but should note that the methodology uses regional averages not directly applicable to specific operations dependent on local conditions.*

PigGas has therefore been designed to calculate piggery-specific emissions. Reference to calculations is made in this report and in the PigGas Calculator spreadsheet to the methodology reported in the National Greenhouse Account Factors, July 2011 (DCCEE 2011a)and the most recent 'Australian National Greenhouse Accounts - National Inventory Report 2010 Volume 1' (DCCEE 2012).

PigGas was developed as a relatively simple tool for pig farmers to carry out these emissions calculations for their own site, energy usages, production systems, feeds and growth performance, waste management systems and manure re-use and soil application methods.

PigGas calculates the piggery enterprise Scope 1 and Scope 2 emissions over which the pig farmer has some immediate control. Scope 1 or direct emissions are a direct result of the piggery activities and on-site combustion of fuels. Scope 2 or indirect emissions result from consumption of electricity purchased off-site.

PigGas does not calculate detailed Scope 3 or 'lifecycle' emissions in the broader upstream or downstream supply chain outside the enterprise boundary e.g., manufacture of purchased feedstuffs, piggery supplies, off-site pig transport or processing. However, it does provide an option to select and input some simplified average estimates of some of these which can be sourced from industry 'life cycle assessment' research. Alternatively, Scope 3 emissions can be input using data derived from other calculator programs such as the Australian Farm Institute's 'FarmGAS' model (http://calculator.farminstitute.org.au/login) or, the Department of Climate Change and Energy Efficiency's 'Fullcam' model (http://www.climatechange.gov.au/government/initiatives/ncat/~/media/publications/carbon-accounting/toolbox-cd/fullcam-usermanual.pdf) or,
the 'SimaPro' life cycle assessment software (http://www.pre.nl/content/simapro-lca-software).

The calculation output or carbon footprint is calculated as kilograms of carbon dioxide equivalents (kg CO_2-e) for the defined piggery enterprise and also as an intensity figure of kilograms of carbon dioxide equivalents per kilogram of hot standard carcass weight (kg CO_2-e / kg HSCW).

PigGas Emissions Boundary Schematic

For a piggery enterprise, the defined boundary and emission profile calculated in PigGas is summarised schematically in Figure 1 below. The on-farm emissions are described in detail in the section below titled 'Comparison of default Australian methodology with PigGas methodology for estimating greenhouse gas emissions for pigs'.

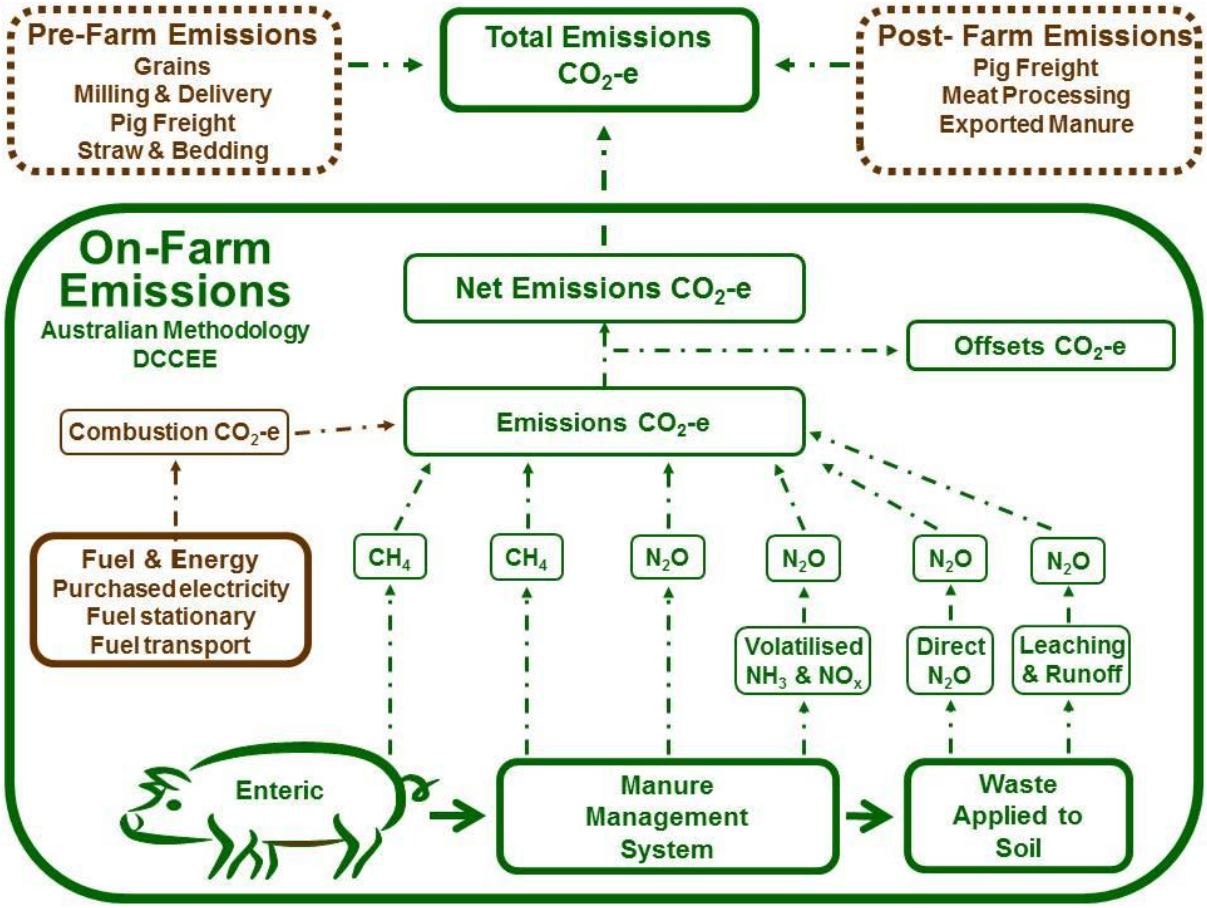


Figure 1: PigGas - Piggery greenhouse gas emissions diagram

Emissions 'offsets' (trees, soil carbon etc) can be entered if options and estimates are available in the future, however, any offsets need to be estimated from other sources and CO_2-e emissions data is entered manually.

'Pre-farm' Scope 3 emissions (feed grain, straw/bedding, feed transport, feed milling, pig freight) and 'post-farm' Scope 3 emissions (pig freight, meat processing, manure exported off-site) are separated from the piggery enterprise boundary. These emissions (with the exception of manure export) can be reported in PigGas separately if estimates are gathered from other sources and CO_2-e emissions data entered manually. For any manure (solids or effluent) that is exported off-site, PigGas reduces 'on-farm' methane and nitrous oxide emissions in proportion to the percentage of volatile solids and nitrogen exported, and it also assumes that any solids or effluent exported will be applied to soil off-site resulting in N_2O emissions elsewhere. These 'exported manure' emissions are counted as a 'post-farm emissions' component.

PigGas calculates only those emissions directly attributable to the piggery enterprise, and excludes other livestock enterprise emissions, pasture/cropping enterprise emissions or field burning of agricultural residues.

While there may be some cross-over of soil emissions with other farm enterprises, these other farm emissions are not considered as part of the PigGas calculations. If there is a need to determine emissions for other farm enterprises, this can be done by using the calculator called 'FarmGAS' on the website of the Australian Farm Institute (http://calculator.farminstitute.org.au/login). FarmGAS has a simple pig enterprise module, but the module does not provide the detailed enterprise fine-tuning that is built into the 'PigGas' Calculator.

Comparison of Default Australian Methodology (DCCEE 2011a) with PigGas Calculator Methodology for Estimating Greenhouse Gas Emissions for Pigs

Greenhouse Gas Global Warming Potentials

Default (DCCEE 2011a)

The major piggery-related greenhouse gas emissions are methane (CH_4) and nitrous oxide (N_2O). Factors for converting these emissions to global warming potentials in terms of carbon dioxide equivalents (CO_2-e) are shown in Table 26 below.

Table 26: Global warming potentials (DCCEE 2011a)

Greenhouse gas	Conversion factor
Carbon dioxide (CO_2)	1
Methane – CH_4	21
Nitrous oxide – N_2O	310

PigGas

Same as default above.

Fuel Combustion - Stationary and Mobile (Transport) Sources - ($C0_2$-e)

Default (DCCEE 2011a)

CO_2-e (t) = Quantity of fuel type (kL) x Energy content factor of fuel type (GJ/kL) x Emission factor for each GHG (kg CO2-e / GJ) from Tables 3 & 4 of DCCEE 2011a.

PigGas

Same as default methodology, but PigGas has restricted selections to the following options:

- For stationary fuels- petrol, heating oil, diesel, LPG, biodiesel.
- For mobile (transport) fuels – petrol, diesel, LPG, biodiesel.

Tables 3 & 4: Combined data - fuel combustion emissions factors used for stationary & transport energy purposes (DCCEE 2011a)

Fuel Combusted	Energy (GJ/kl)	Emission Factors kgCO2-e/GJ		
		CO2	CH4	N20
Petrol (Stationary)	34.20	66.70	0.20	0.20
Heating Oil (Stationary)	37.30	68.80	0.02	0.20
Diesel (Stationary)	38.60	69.20	0.10	0.20
Biodiesel (Stationary)	34.60	0.00	0.06	0.20
LPG (Stationary)	25.70	59.60	0.10	0.20
Petrol (Transport	34.20	66.70	0.60	2.30
Diesel(Transport)	38.60	69.20	0.20	0.50
Biodiesel (Transport)	34.60	0.00	1.20	2.20
LPG (Transport)	26.20	59.60	0.60	0.60

Consumption of Electricity Purchased Off-Site - ($C0_2$-e)

Default (DCCEE 2011a)

CO_2-e (t) = Quantity of electricity purchased (kW.h) x Emission factor for state grid (kg CO2-e / kW.h) from Table 5 of DCCEE 2011a.

Table 5: Indirect (scope 2) emission factors for consumption of purchased electricity from the grid (National Greenhouse Accounts Factors - DCCEE 2011a)

State	Emission factor kg CO2-e/kWh
ACT	0.89
NSW	0.89
Tasmania	0.30
Western Australia	0.80
South Australia	0.68
Victoria	1.21
Queensland	0.88
Northern Territory	0.67

PigGas

Same as default methodology.

Pig Classes

Default (DCCEE 2012, Section 6.3.2.3 Pigs)

Pig Classes: Boars, Sows, Gilts, Others (average) from Table 6.7 of DCCEE 2012.

Pig numbers: obtained from state pig population statistics. Weaner, grower and finisher pigs are not analysed separately.

PigGas
Piggery Unit: Up to 10 separate piggery units can be named for the piggery. This is a specific farm identifier known to the operator, e.g. Breeder 1, Grower unit, Multiplier, Weaner 3 etc.
Pig Groups: Up to 50 separate groups can be named for the piggery. This is a specific farm identifier of a discrete group of pigs within a particular pig category in a piggery location or unit as described by the operator, e.g. 2nd stage weaner, shed2 porker, outdoor dry sows etc.
Pig Categories: Up to 10 categories available for naming of each group. This is a specific farm identifier of the type or class of pigs within a particular piggery as usually described by the operator, e.g. boar, lactating sow, dry sow, gilt, sucker, nursery, weaner, porker, grower, finisher, baconer, presale etc.
Pig numbers, groups and categories for each piggery unit are derived from on-farm records.

Diets & Pig Production Data
Default (DCCEE 2012, Appendix 6.E Pigs)
Uses standardised data sets, derived from PIGBAL Version 2.14 (Casey et al 1996), of average feed specifications and average herd characteristics to calculate feed intakes (Table 6.E.1), volatile solids in the waste (Table 6.E.2) and nitrogen in the waste (Table 6.E.5). This data for year 2000+ is shown below:

Tables 6.E.1 & 6.E.2 & 6.E.5: combined data for year 2000+ (DCCEE 2012)

	Boars	**Gilts**	**Breeding sows**	**Other pigs**
Feed intake (kgDM/hd/d) Table 6.E.1	2.20	2.80	3.02	1.49
Volatile solids (kg/hd/d) Table 6.E.2	0.39	0.54	0.49	0.28
Nitrogen (kg/hd/d) Table 6.E.5	14.59	12.23	20.70	11.04

A default gross energy factor of 18.6 MJ GE/kg feed DM is used in enteric methane calculation.

PigGas
Uses farm-specific feed specifications, feed intakes, feed wastage and herd production performance for each pig group to calculate the volatile solids and nitrogen in waste streams.

The raw ingredients of up to four separate (seasonal) diets for each pig group can be entered into PigGas to calculate dietary gross energy for enteric methane calculations, and manure volatile solids and nitrogen for methane and nitrous oxide calculations from the manure management systems and wastes applied to soils. If more than one diet is used for a group, calculations are based on the percentage of each diet consumed throughout the year.

The standard raw ingredients list used in PigGas was obtained from the latest version of PIGBAL which is currently being updated for release in 2013. This list includes gross energy, dry matter digestibility, ash and nitrogen concentrations for raw dietary ingredients.

The method used in PigGas to calculate manure volatile solids and nitrogen outputs is the same as used in PIGBAL i.e., by summing the volatile solids and nitrogen compositions of the diet ingredients used for each pig group.

The gross energy of each diet for each group of pigs is calculated in the same way and used instead of the default value of 18.6 MJ GE/kg feed DM in the calculation of enteric methane.

An alternative method is available for obtaining dietary gross energy and nitrogen. Gross energy (GE) is not reported in pork industry diet summaries and some farmers may only have access to diet analysis summaries which include digestible energy (DE), fibre, ash, nitrogen and other included nutrients without knowing the detailed raw ingredients list for their purchased feeds. In this case, PigGas provides an estimation equation for gross dietary energy derived from entries of DE, fibre and ash content. This regression equation was derived from the composition of DE, fibre and ash in the standard raw ingredients list used in PigGas. The nitrogen content of the total diet can be entered directly into PigGas in this case.

Enteric Methane - (CH_4)

Default (DCCEE 2012, Section 6.3.2.3 Pigs)

Methane (kg/d) = feed intake (kg DM/d) x 18.6 (MJ GE/kg DM intake) x 0.007 (methane conversion factor of gross energy) / 55.22 (MJ/kg methane) ……**Equation 4A.8_1**

Dietary gross energy is assumed to be constant for all pig classes at 18.6 MJ/kg feed dry matter.

A methane conversion of 0.7% of gross energy intake is used for Australia.
Appendix 6.E.1 gives approximate dry matter intakes for Boars, Sows, Gilts and Others. (see above section 'Diets & pig production data'.)

Uses an average value for gross energy of feed for all pig classes of 18.6 MJ GE / kg feed DM. This is derived from average herd performance characteristics (Table I.3), average feed specification, intake and wastage (Tables G.1, I.1, I.2 and I.3, DCCEE 212)

PigGas

Methane (kg/d) = feed intake (kg DM/d) x **on-farm diet gross energy** (MJ GE/kg DM intake) x 0.007 (methane conversion factor of gross energy) / 55.22 (MJ/kg methane)……..**Equation 4A.8_1**

Uses farm-specific feed intakes for each pig group. Uses farm-specific feed specifications or diet analyses and a current feed ingredient raw material list to calculate gross energies in diets for each pig group.

Manure Management Systems Descriptors

Default (DCCEE 2012, Appendix 6.E Pigs)

Manure management systems (MMS) options (Tables 6.E.3 and Table 6.12) are only broadly defined as follows:

MMS1 – Anaerobic lagoon
MMS2 – Liquid/slurry system
MMS3 – Daily spread
MMS4 – Solid storage & drylot
MMS5 – Digester

Australian Methodology allocates set proportions of manure management systems to each state (Table 6.E.3).

Table 6.E.3: Pigs – Allocation of waste to manure management systems - (DCCEE 2012)

State	Manure Management System				
	MMS1 Lagoon (%)	MMS2 Liquid / Slurry (%)	MMS4 Drylot (%)	MMS3 Daily Spread (%)	MMS5 Digester (%)
NSW /ACT	73	0	0	27	0
Tasmania	0	0	0	100	0
Western Australia	65	0	30	5	0
South Australia	73	0	0	27	0
Victoria	71	0	0	27	2
Queensland	92	1.5	5	1.5	0
Northern Territory	100	0	0	0	0

Table 6.12: Symbols and emission factors used in algorithms for nitrous oxide emissions – (DCCEE 2012)

Manure Management System (MMS)	Emission Factor (kg N20-N / kg N excreted)
MMS1 - Anaerobic lagoon	0.001
MMS2 - Liquid systems	0.001
MMS3 - Daily spread	0
MMS4 - Solid storage & drylot	0.02
MMS5 - Digester	0.001

PigGas

More detailed choices for waste treatment and solid separation options reflecting Australian piggeries are built into PigGas. Multiple manure management systems on a piggery site can be modelled by enabling different manure management systems to be allocated to different pig groups on the site.

The following assumptions have been made to allow individual piggeries to adequately define and allocate their systems to a default MMS descriptor.

Anaerobic Lagoon
All piggery pond/lagoon treatment systems (including evaporation basins, facultative ponds and sedimentation & evaporation ponds) with surfaces open to the atmosphere are included in this system descriptor.

Liquid/Slurry System
All piggery waste systems in which effluent is stored for more than one day and is then spread by irrigation or tanker without going through a treatment pond or lagoon are included in this system descriptor. (An example is underfloor storage for a several weeks followed by pump-out and tanker spreading to a paddock.)

Daily Spread
This descriptor includes all piggery waste collection systems which store effluent for one day or less and are spread daily by irrigation or tanker. It also includes all outdoor pigs which do not have associated deep litter housing, since their manure is deposited daily on the soil.

Solid Storage & Drylot
All deep litter or eco-shed type production systems for any class of pigs are incorporated in this system descriptor. Also includes all outdoor pigs which have deep litter shelters with access to outdoor paddocks or runs.

Digester
This descriptor includes all constructed manure digestion facilities (including covered anaerobic ponds) which capture and consume the methane by flaring or combustion in engines or gas-fired boilers, heaters etc.

Manure Management System - (CH_4)
Default (DCCEE 2012, Section 6.4.2.3 Pigs)
Methane (kg/d) = volatile solids (kg/d) x 0.45 (m^3 methane/kg volatile solids) x methane conversion factor (Table 6.E.4) x 0.662 (kg/m3 methane)……..**Equation 4B.8_1**

Uses average volatile solids production calculated from PIGBAL (Casey et al, 2000) with average feed specifications, intakes and wastage for limited pig classes (Table 6.E.2 – see above in 'Diets and pig production data' section).

Uses an integrated methane conversion factor (MCF) for each state (Table 6.E.4 below) based on an assumed allocation of different percentages of manure management options in each state (Table 6.E.3 – see above in 'Manure management systems descriptors' section).

Table 6.E.4: Pigs – Methane Conversion Factor (MCF) – (DCCEE 2012)

State	Manure Management System - MCF				
	MMS1 Lagoon (%)	**MMS2 Liquid / Slurry (%)**	**MMS4 Drylot (%)**	**MMS3 Daily Spread (%)**	**MMS5 Digester (%)**
NSW / ACT	90	35	1.5	0.5	10
Tasmania	90	35	1.5	0.5	10
Western Australia	90	35	1.5	0.5	10
South Australia	90	35	1.5	0.5	10
Victoria	90	35	1.5	0.5	10
Queensland	90	65	5.0	1.0	10
Northern Territory	90	65	5.0	1.0	10

PigGas

Methane (kg/d) = **on-farm diet volatile solids** (kg/d) x 0.45 (m^3 methane/kg volatile solids) x methane conversion factor (Table 6.E.4) x 0.662 (kg/m3 methane) …..……..**Equation 4B.8_1**

PigGas uses farm-specific feed specifications, intakes, wastage and herd production performance for each pig group on-site to calculate volatile solids in waste streams from a current feed ingredient raw materials list using the same mass balance method as PIGBAL.

PigGas uses the default methane conversion factors (MCF) for individual farm-specific manure management system options as outlined in Table 6.E.4 above, and apportions waste streams from different on-farm pig groups to different manure management systems (MMS).

Manure Management System - (N_2O)

Default (DCCEE 2012, Section 6.4.2.3 Pigs)

Nitrogen in waste (kg/d) = number of pigs x nitrogen in waste from Table 6.E.5 (kg/head/d)

……..**Equation 4B.8_3**

Nitrous oxide emissions (kg) = nitrogen in waste (kg/d) x emission factor (Table 6.12) x 44/ 28

……..**Equation 4B.8_4**

Uses averaged nitrogen production (Table 6.E.5) calculated from PIGBAL (Casey et al, 2000) with average feed specifications, intakes and wastage for limited pig classes.

Allocates generic waste management options based on an assumed allocation of different percentages of manure management options in each state (Table 6.E.3) and associated emission factors (Table 6.12).

Table 6.12: Symbols and emission factors used in algorithms for nitrous oxide emissions – (DCCEE 2012)

Manure Management System (MMS)	Emission Factor (kg N20-N / kg N excreted)
MMS1 - Anaerobic lagoon	0.001
MMS2 - Liquid systems	0.001
MMS3 - Daily spread	0
MMS4 - Solid storage & drylot	0.02
MMS5 - Digester	0.001

PigGas

Nitrogen in waste (kg/d) = number of pigs x **on-farm nitrogen in waste** (kg/head/d)

……..……**Equation 4B.8_3**

Nitrous oxide emissions (kg) = nitrogen in waste (kg/d) x emission factor (Table 9) x 44 / 28

……..**Equation 4B.8_4**

Uses farm-specific feed specifications, intakes, wastage and herd production performance for each pig group to calculate nitrogen in waste streams from a current feed ingredient raw materials list using the same mass balance method as PIGBAL.

Uses individual farm-specific manure management system options and the default emission factors as outlined in Table 6.12 (above).

PigGas apportions waste streams from different on-farm pig groups to different manure management systems (MMS).

Manure Management System (Volatilised NH_3 & NO_x) – (N_2O)

Default (DCCEE 2012, Section 6.6.2.7 Atmospheric Deposition)

Nitrous oxide emissions (kg) = nitrogen in waste (kg/d) for each MMS x fraction volatilised from each MMS in Table 6.31 (FracGASM) x 0.01 (kg N_20-N/kg N) x 44/28

…….……. **(Equations 4D3_2 and 4D3_4)**

Table 6.31: Fraction of N volatilised in each manure management system (FracGASM) – (DCCEE 2012)

Manure management system	Swine
MMS1 - Anaerobic lagoon	0.4
MMS2 - Liquid slurry	0.48
MMS3 - Daily spread	0.07
MMS4 - Solid storage & drylot	0.45
MMS5 - Digester	0

PigGas

Nitrous oxide emissions (kg) = **on-farm nitrogen in waste** (kg/d) for each MMS x fraction volatilised from each MMS in Table 6.31 (FracGASM) x 0.01 (kg N_20-N/kg N) x 44/28

…….……. **(Equations 4D3_2 and 4D3_4)**

Uses farm-specific feed specifications, intakes, wastage and herd production performance for each pig group to calculate nitrogen in waste streams from a current feed ingredient raw materials list with the same mass balance method as used in PIGBAL.

Uses individual farm-specific manure management system options and the default emission factors as outlined in Table 6.31 (above).

PigGas apportions waste streams from different on-farm pig groups to different manure management systems (MMS).

Wastes Applied to Soils (Direct) – (N_2O)

Default (DCCEE 2012 Section 6.6.2.2 Animal Wastes Applied to Soils)

Mass of nitrogen applied to soils (kg) = Mass of nitrogen excreted (kg) - mass of nitrogen (kg) lost as N_20 during storage – mass of nitrogen (kg) lost as NH_3 and NO_X during storage in the different manure management systems……..…… **(Equation 4D1_3)**

Mass of nitrous oxide emitted from soils (kg) = Mass of nitrogen applied to soils(kg) x 0.01 (kg N_20 / kg N applied) ……..…… **(Equation4D1_4)**

PigGas

Same as default methodology above.

Uses farm-specific feed specifications, intakes, wastage and herd production performance for each pig group to calculate nitrogen in waste streams from a current feed ingredient raw materials list with the same mass balance method as used in PIGBAL. Uses farm-specific manure management system options for individual pig groups to apportion nitrogen flows.

Wastes Applied to Soils (Leaching & Runoff) – (N_2O)

Default (DCCEE 2012, Section 6.6.2.8 Leaching and Runoff)

Mass of nitrogen lost through leaching and runoff (kg) = Mass of manure nitrogen applied to soils (kg) x FracWET from Table 6.J.2 x 0.3 (kg N lost/kg N applied) …..…… **(Equation 4D3_6)**

Mass of N_2O lost through leaching and runoff (kg) = Mass of N lost through leaching and runoff (kg) from Equation 4D3_6 above x 0.0125 (kg N_20 / kg N) x 44/28.....**(Equation 4D3_7)**

Table 6.J.2: Fraction of animal waste available for leaching and runoff (FracWET) – (DCCEE 2012)

State	All other categories (including swine)
ACT	0.665
NSW	0.335
Northern Territory	0.773
Queensland	0.107
South Australia	0.415
Tasmania	0.995
Victoria	0.768
Western Australia	0.668

PigGas
Same as default methodology above.

Uses farm-specific feed specifications, intakes, wastage and herd production performance for each pig group to calculate nitrogen in waste streams from a current feed ingredient raw materials list with the same mass balance method as used in PIGBAL. Uses farm-specific manure management system options for individual pig groups to apportion nitrogen flows.

Additional Notes on Default Australian Methodology vs PigGas
Direct CO_2 Emissions
According to Australian Methodology, any CO_2 produced directly by pigs or by manure management systems are considered part of the natural carbon cycle and not considered in estimation of GHG.

Outdoor Piggeries
The Australian Methodology assumes that all pig waste nitrogen is applied to soils after waste treatment, or is daily spread. The ruminant option 'pasture range and paddock', is not available for outdoor pigs. For outdoor piggeries, PigGas allocates different types of outdoor piggeries into realistic manure management system categories as outlined in 'Manure management descriptors' section above.

Piggery Production and Diets
The Australian Methodology assumes diets with a default energy level of 18.6MJ whereas modern piggery diets fall between 16 &17MJ. PigGas allows on-farm dietary input for each pig class.

PigGas calculations assume that a steady state or average level of production occurs in the piggery enterprise during the whole year. Producers can enter up to four pig diets for each identified pig class or pig group as well as entry and exit weights and ages to match steady state on-farm growth performance of each group.

Multiple Waste Treatment Systems

The Australian Methodology does not account for multiple losses or reductions in nitrogen and volatile solids through complex or multiple waste treatment and reuse systems (including solids separation, composting and storage, different types of pond treatment systems and residence times) which can occur on an individual piggery. Therefore, errors probably occur in the Australian Methodology due to simplification of some piggery systems and use of default international emission rates rather than emissions research from Australian piggeries.

PigGas allows the setup of unique combinations waste collection, solid extraction, solids use, liquid treatment, and treated effluent use for each group of pigs on a site.

Separated Solids

This section is inserted as a new MMS 3 (solids storage/drylot) stream which can be added to any pig group waste management system. Maximum percentages of volatile solids and nitrogen removed by various separation methods are shown in the following table. The data was synthesized from Kruger et al (1995) and Tucker et al (2010). The data can be changed in the Assumptions Menu screen. The 'Daily Spread' option is inserted into solids separation table for selection in the instance where a proportion of the effluent is diverted to land or exported prior to entering a waste treatment system (e.g., say 20% of piggery manure is taken from a sump each day to be spread by tanker, remaining 80% goes to pond treatment etc.)

Solids Separation Method	**%VS**	**%N**
None	0	0
Run-down screen	15	5
Screw press	20	7.5
Centrifuge	25	10
Sedimentation	50	20
Daily Spread	20	20

Exported Solids and Effluent

A legitimate pathway for solids or effluent from a piggery is removal of a percentage through off-site export or sales. The remainder goes to soil application within the piggery enterprise. The off-site export or sales portion need not be accounted for in piggery enterprise emissions as it would normally be used by another farm in a cropping, pasture or livestock enterprise where it would be accounted for as organic (manure) fertiliser in their own farm emissions estimates. PigGas accounts for this in the reporting of Post-Farm Emissions.

A separate waste stream for the sludge from ponds and digesters is not incorporated in PigGas options, because emissions calculations for the manure management systems already incorporates the combined effluent and sludge portions. Effluent can be exported off-site and is assumed to comprise the remaining nitrogen in both the effluent and the sludge.

Reporting CO_2-e Emissions

For every piggery greenhouse gas emission sub-category shown in Figure 1, PigGas reports total annual CO_2-e emissions as kg CO_2-e/yr and also emissions intensity as kg CO_2-e / kg HSCW (Hot Standard Carcass Weight). To enable the intensity calculation, pig slaughter numbers and carcass weights are entered into PigGas for each piggery unit.

PigGas Calculator User Guide

The PigGas (.xlsm) file should be preferably be opened in Microsoft Excel 2010 software. Earlier versions of Microsoft Excel should convert, open and run the file.

The file should open at the Main Menu page. If not, a Menu button can be found on each data entry screen which takes you back to the Main Menu page as shown below in Figure 4.

Main Menu (Figure 2)

- Follow the arrows on the Main Menu entry screen. By clicking on the various sub-Menus such as Farm Details, Manure Management, Diets etc, and fill in the details required at each new screen. It is possible to go back to the Main Menu screen by clicking the Menu button located on each data entry screen.

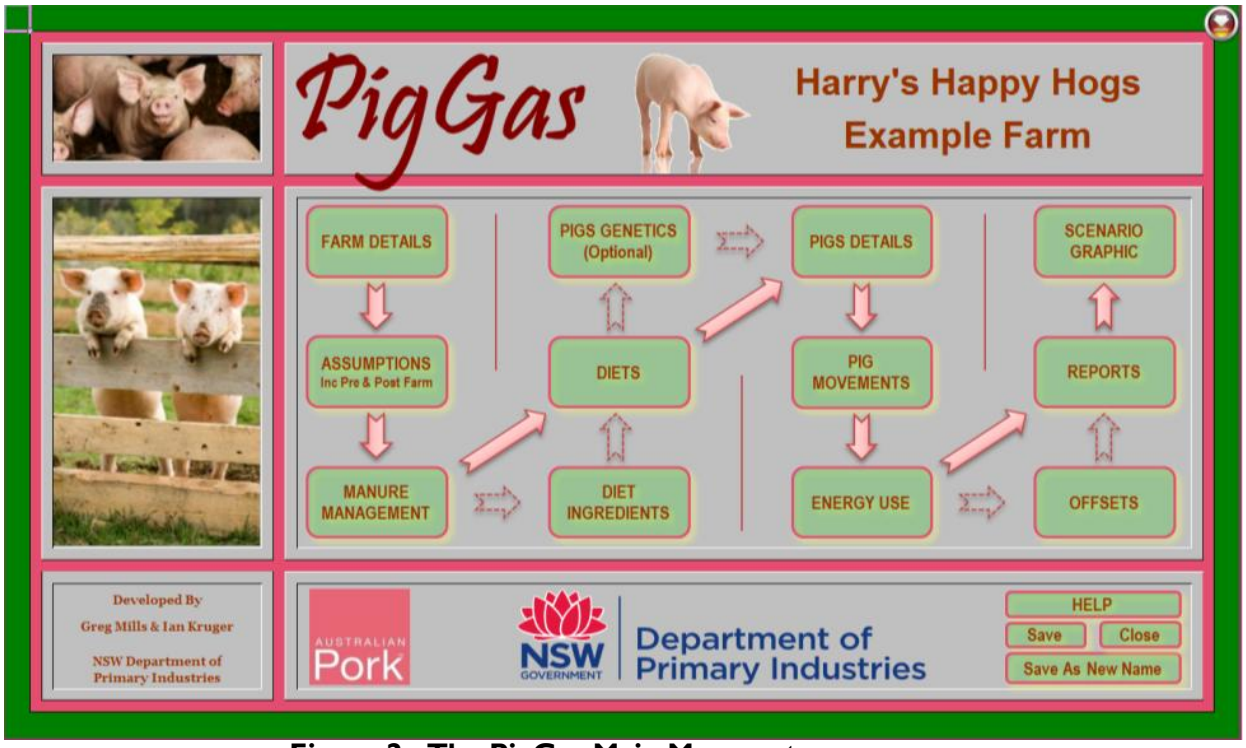


Figure 2: The PigGas Main Menu entry screen

Farm Details Menu (Figure 3)

- Open the Farm Details screen by clicking on Farm Details button in Main Menu.
- In the State box, select from drop-down list.
- In Business Name box, type business or owners name into space provided.
- In Project Title box, type a title for the emisions study e.g, Baseline GHG Emissions.
- In Unit Name boxes, type piggery unit names for the site. These unit names will be used by the program to identify where to allocate individual pig groups, waste treatment systems and energy uses. These should names familiar to piggery staff.

Figure 3: Farm Details entry screen

- In Pig Categories boxes, in the left hand column, type all known cartegories of pigs on site using terminology or names familiar to staff, e.g., Dry sows, Nursery, Weaner2, Finisher etc.
- In Pig Categories' boxes, in the right hand column, click each box and choose from either Breeder or Grower in the drop down list to describe the category.
- In Diet Names boxes, type every diet name used on the site.
- Click Menu button to return to Main Menu.

Assumptions Menu (Figure 4)

- Open the Assumptions screen by clicking Assumptions button in Main Menu.

To enable calculation to be made of both Pre-Farm and Post-Farm Emissions, data estimates need to be entered for the following:

- Grains – assumed 250 kg CO_2-e/t grain (Wiedemann et al, 2009)
- Straw & bedding - assumed 25 kg CO_2-e/t straw (1/10th grain in lieu of literature data)
- Feed milling & delivery – assumed average 48 kg CO_2-e/t feed (Wiedemann et al ,2009)
- Meat processing – assumed average 0.4 kg CO_2-e/kg HSCW (Wiedemann et al, 2009)

(Note: this data can be drawn from any suitable published Australian data sources.)

Also, the following data need to entered based on known transport information for the site:

Pig Purchased Transport

- Pigs per load (Hd)
- Distance (km)
- Fuel (L/100km)

Pig Sales Transport

- Pigs per load (Hd)
- Distance (km)
- Fuel consumption (L/100 km)

Also, to enable calculations of emissions intensity where pigs are imported to a site,

- Dressing % for Transfers & Purchases - assumed 76% (use best site estimate

Also, to enable solids removal calculations for the manure management systems,

- Maximum percentages of volatile solids and nitrogen removed by various separation methods are shown in the following table. The data was synthesized from Kruger et al (1995) and Tucker et al (2010). The data can be changed if warranted in the Assumptions entry screen. The 'Daily Spread' option is inserted into the solids extraction separation table for selection in the instance where a proportion of the effluent is diverted to land spreading or exported prior_to entering a waste treatment system (e.g., 20% of piggery manure is taken from a sump each day to be spread by tanker, remaining 80% goes to pond treatment etc.)
- Click Menu button to return to Main Menu.

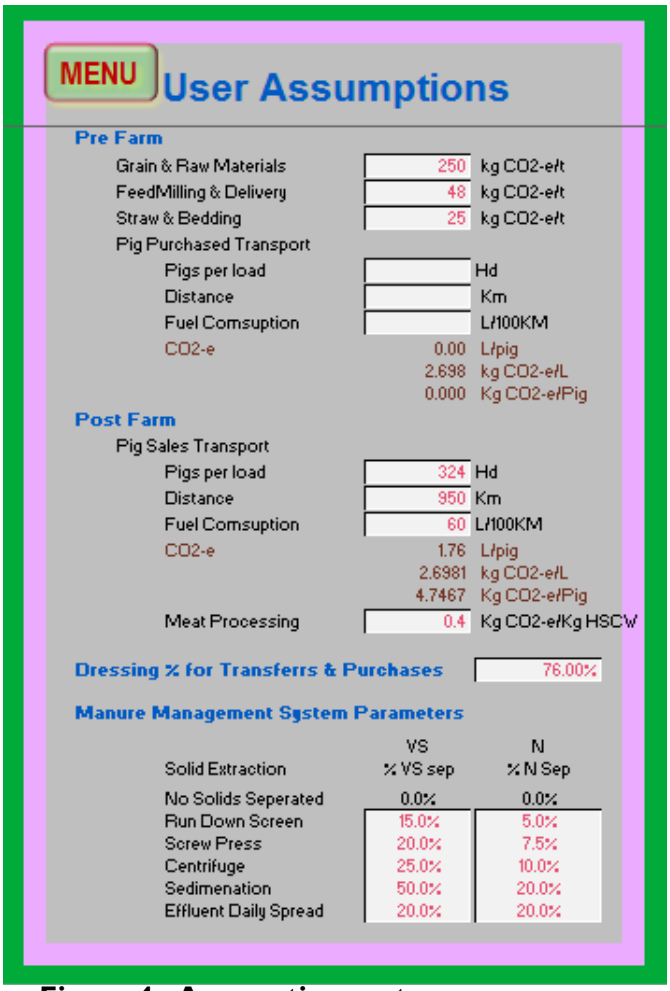


Figure 4: Assumptions entry screen

Manure Management Systems Menu (Figures 5 & 6)

- From the Main Menu screen, click on the Manure Management button.
- Five Manure Management Systems (MMS1 to MMS5) can be configured for the site.
- Clicking on each MMS opens individual entry screens.

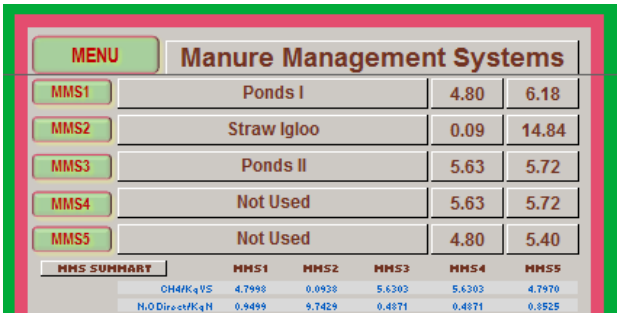


Figure 5: Manure Management Systems screen

- As an example, click on the first button (MMS1) to open its entry screen (see Figure 6).
- Each manure management system on the piggery site should be named and defined in detail by clicking on the entry boxes which appear on the screen (see Figure 6). These systems can then be allocated later to individual pig groups on the site.
- Click Menu button to return to Main Menu.

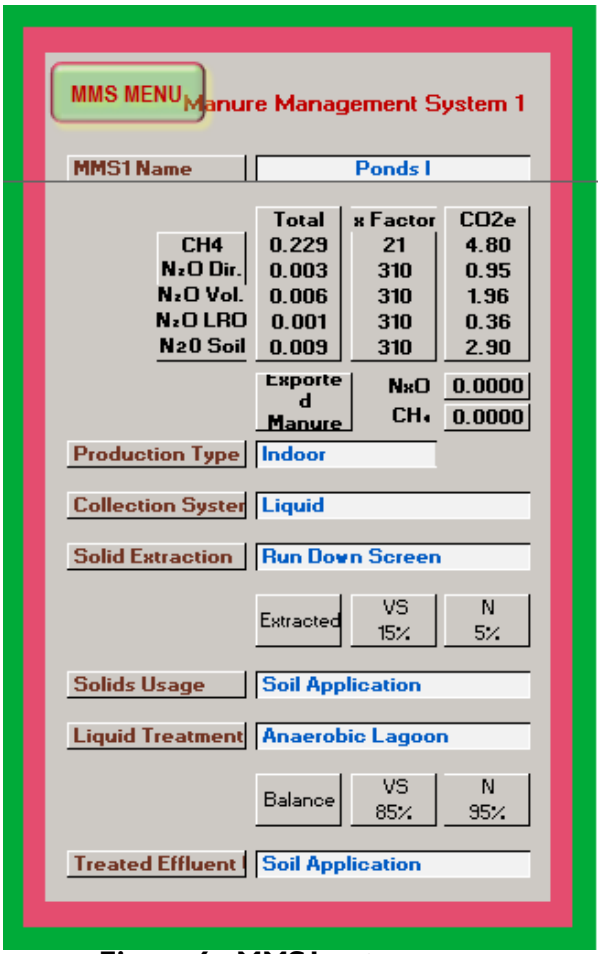


Figure 6: MMS1 entry screen

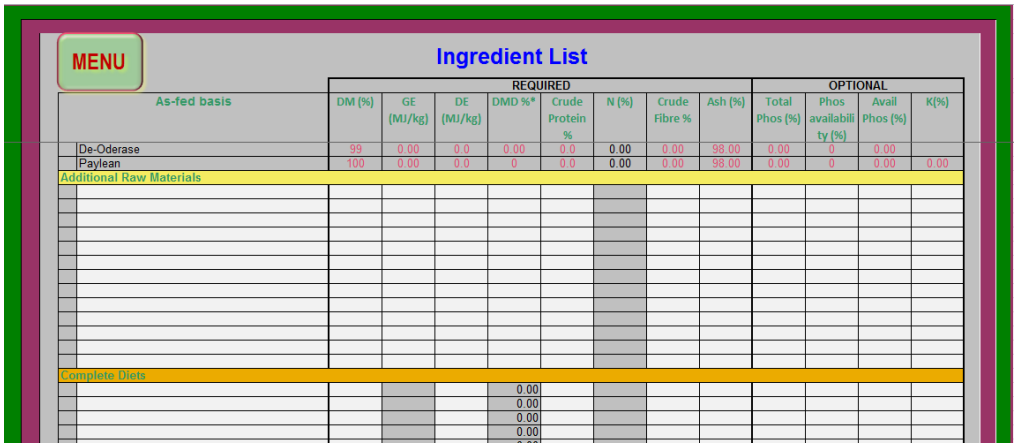
Diet Ingredients Menu – Optional (Figures 7 & 8)

- From the Main Menu screen, click on the Diet Ingredients button.
- A fixed pig diet Ingredients List is included in PigGas (which matches PigBal Version 2013). This list is used to calculate mass balances of volatile solids and nitrogen.

As-fed basis	REQUIRED DM (%)	GE (MJ/kg)	DE (MJ/kg)	DMD %*	Crude Protein %	N (%)	Crude Fibre %	Ash (%)	OPTIONAL Total Phos (%)	Phos availability (%)	Avail Phos (%)	K(%)
Cereal Grains												
Barley 11	88	16.00	12.8	0.80	11.0	1.76	4.55	2.25	0.36	35	0.13	0.47
Groats	90	16.06	15.0	0.93	11.0	1.76	1.80	2.14	0.30	32	0.10	0.35
Maize 8	88	16.13	14.5	0.90	8.0	1.28	2.15	1.21	0.26	28	0.07	0.33
Naked oats	88	17.48	15.7	0.90	10.0	1.60	2.50	1.80	0.46	34	0.16	0.36
Oats 9	88	17.15	12.0	0.70	9.0	1.44	12.19	2.64	0.32	32	0.10	0.36
Sorghum 11	88	16.28	14.2	0.87	11.0	1.76	2.30	2.00	0.28	20	0.06	0.35
Triticale 11	88	15.75	14.0	0.89	11.0	1.76	2.30	1.92	0.35	40	0.14	0.50
Wheat 12	88	16.22	14.3	0.88	12.0	1.92	2.00	1.70	0.34	50	0.17	0.41
Wheat Extruded	88	16.22	15.2	0.94	12.0	1.92	2.00	1.70	0.34	50	0.17	0.41
Cereal by-products												
Hominy Meal	89	16.98	14.6	0.86	13.4	2.14	5.52	4.65	0.77	21	0.16	0.00
Millrun	87	16.50	11.5	0.70	15.0	2.40	9.00	5.00	0.95	29	0.28	0.80
Rice Hulls	89	16.00	2.5	0.16	2.0	0.32	40.00	5.00	0.07	30	0.02	—
Rice bran	90	16.00	7.7	0.48	15.5	2.48	14.00	13.00	1.70	20	0.34	1.15
Rice Pollard	88	16.66	15.7	0.94	15.0	2.40	9.00	1.41	1.20	33	0.40	1.17
Wheat Bran	87	16.44	9.4	0.57	15.0	2.40	9.20	5.05	0.99	30	0.30	0.40
Wheat Pollard	87	16.53	11.2	0.68	15.0	2.40	8.50	4.70	0.95	29	0.28	1.20
Roots & Tubers												
Cassava	87	14.50	12.8	0.88	3.0	0.48	4.50	5.50	0.09	10	0.01	0.85
By-products												
Biscuit Meal	89	17.00	15.1	0.89	10.0	1.60	1.00	3.00	0.35	43	0.15	0.39

Figure 7: Diet Ingredients entry screen

- 'Additional Raw Materials' can be added to the Ingredients List if composition is available. (see Figure 8). Also, if diet ingredients are unavailable for pig groups , but the composition of the total diets are available, these can be entered as 'Complete Diets' in rows at the bottom of the Ingredients List (See Figure 8).
- Click Menu button to return to Main Menu.



As-fed basis	REQUIRED DM (%)	GE (MJ/kg)	DE (MJ/kg)	DMD %*	Crude Protein %	N (%)	Crude Fibre %	Ash (%)	OPTIONAL Total Phos (%)	Phos availability (%)	Avail Phos (%)	K(%)
De-Oderase	99	0.00	0.0	0.00	0.0	0.00	0.00	98.00	0.00	0	0.00	
Paylean	100	0.00	0.0	0	0.0	0.00	0.00	98.00	0.00	0	0.00	0.00
Additional Raw Materials												
Complete Diets				0.00								
				0.00								
				0.00								
				0.00								

Figure 8: Entry of 'Additional Raw Materials' and 'Complete Diets' at bottom of Diet Ingredients entry screen

Diets Menu (Figure 9)

- From the Main Menu screen, click on the Diets button.
- Diet Names listed earlier in the Farm Details enty screen will automatically appear as headings for diet entry.
- At the top of the entry screen, enter a Max Total for the diet formulations (mostly diets are formulated to total 100%, but sometimes units totalling 1000 are used).
- For up to 4 diets per year for each pig category, enter the dietary components from feed formulation sheets from feed company or nutritional consultant in the columns.
- Fill in the annual % of Diet Consumed for each diet entered at the top of each diet column.
- Click Menu button to return to Main Menu.

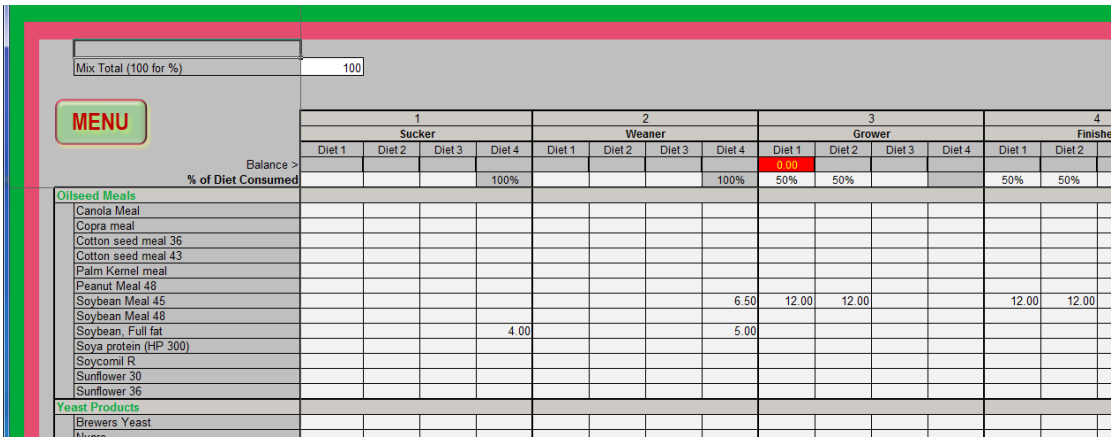
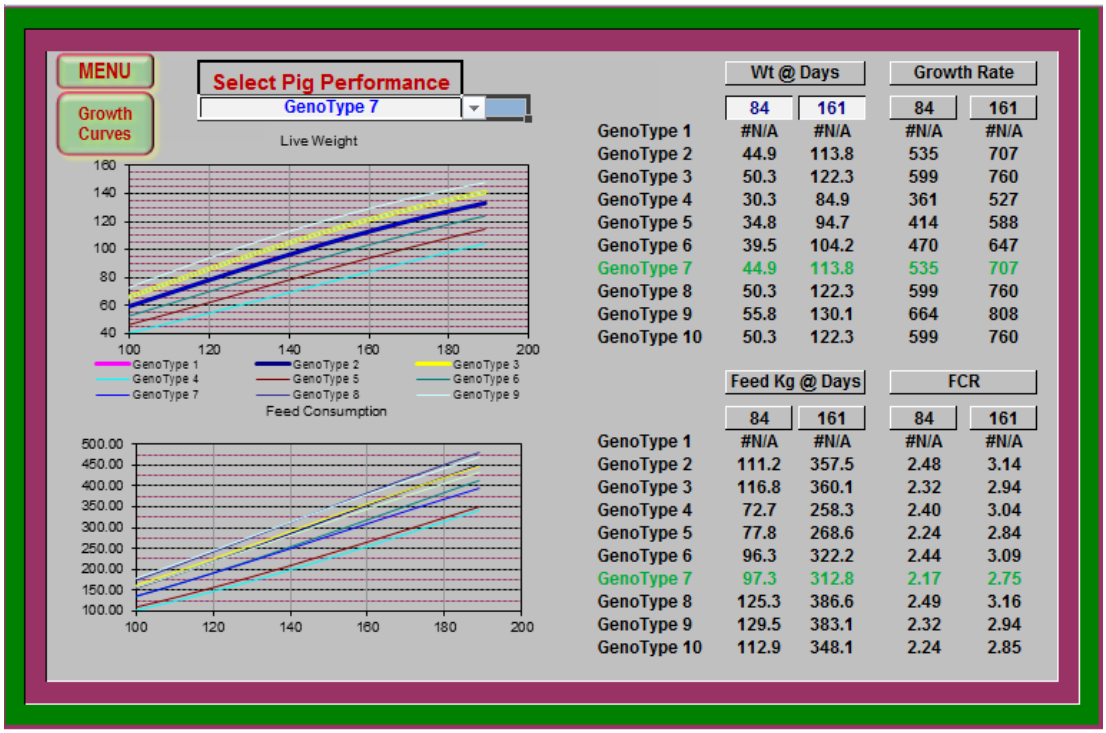


Figure 9: Diets entry screen

Pig Genetics Menu – Optional (Figures 10 & 11)

This menu can be used if detailed records of growth rates and feed intakes for each pig group on-farm are not available or not fully known. This data is needed for entry into the subsequent Pig Details Menu. A pig genotype can be selected which best matches on-farm pig performance.

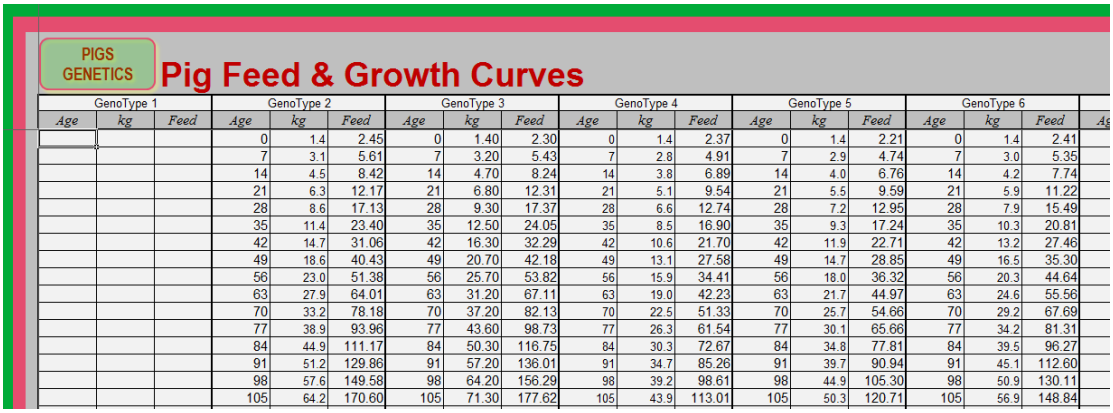
- From the Main Menu screen, click on the Pig Genetics button.
- For a known Pig Group, under the Wt (kg) @ Days title bar at the top right hand side of the entry screen, enter a known transfer age 'In' and 'Out' in the two white boxes. When this is done, weight data, growth rate data, total feed used data and FCR, for GenoTypes 2 to 10 will appear below each age entered. By comparing this data with observed pig performance, a best fit Genetype can be chosen for the piggery.
- GenoType data can then be selected by clicking the box under Select Pig Performance at the top left hand side of the screen and selecting the Genotype from the drop down list.
- Click on the Growth Curves button to view the Pig Feed & Growth Curves screen (Figure 11). GenoType 1 is left blank for producers to input their own GenoTupe performance data if desired.
- This GenoType data selected above will now be available to be loaded into the Pig Details Menu (Figure 12) if all entry ages and weights, exit ages and weights, and feed usage for each PigGroup is not known . (See Help in PigDetails Menu for more information.)
- Click Menu button to return to Main Menu.



	Wt @ Days		Growth Rate	
	84	161	84	161
GenoType 1	#N/A	#N/A	#N/A	#N/A
GenoType 2	44.9	113.8	535	707
GenoType 3	50.3	122.3	599	760
GenoType 4	30.3	84.9	361	527
GenoType 5	34.8	94.7	414	588
GenoType 6	39.5	104.2	470	647
GenoType 7	44.9	113.8	535	707
GenoType 8	50.3	122.3	599	760
GenoType 9	55.8	130.1	664	808
GenoType 10	50.3	122.3	599	760

	Feed Kg @ Days		FCR	
	84	161	84	161
GenoType 1	#N/A	#N/A	#N/A	#N/A
GenoType 2	111.2	357.5	2.48	3.14
GenoType 3	116.8	360.1	2.32	2.94
GenoType 4	72.7	258.3	2.40	3.04
GenoType 5	77.8	268.6	2.24	2.84
GenoType 6	96.3	322.2	2.44	3.09
GenoType 7	97.3	312.8	2.17	2.75
GenoType 8	125.3	386.6	2.49	3.16
GenoType 9	129.5	383.1	2.32	2.94
GenoType 10	112.9	348.1	2.24	2.85

Figure 10: Pig Genetics entry screen



GenoType 1			GenoType 2			GenoType 3			GenoType 4			GenoType 5			GenoType 6		
Age	kg	Feed	Age	kg	Feed	Age	kg	Feed	Age	kg	Feed	Age	kg	Feed	Age	kg	Feed
			0	1.4	2.45	0	1.40	2.30	0	1.4	2.37	0	1.4	2.21	0	1.4	2.41
			7	3.1	5.61	7	3.20	5.43	7	2.8	4.91	7	2.9	4.74	7	3.0	5.35
			14	4.5	8.42	14	4.70	8.24	14	3.8	6.89	14	4.0	6.76	14	4.2	7.74
			21	6.3	12.17	21	6.80	12.31	21	5.1	9.54	21	5.5	9.59	21	5.9	11.22
			28	8.6	17.13	28	9.30	17.37	28	6.6	12.74	28	7.2	12.95	28	7.9	15.49
			35	11.4	23.40	35	12.50	24.05	35	8.5	16.90	35	9.3	17.24	35	10.3	20.81
			42	14.7	31.06	42	16.30	32.29	42	10.6	21.70	42	11.9	22.71	42	13.2	27.46
			49	18.6	40.43	49	20.70	42.18	49	13.1	27.58	49	14.7	28.85	49	16.5	35.30
			56	23.0	51.38	56	25.70	53.82	56	15.9	34.41	56	18.0	36.32	56	20.3	44.64
			63	27.9	64.01	63	31.20	67.11	63	19.0	42.23	63	21.7	44.97	63	24.6	55.56
			70	33.2	78.18	70	37.20	82.13	70	22.5	51.33	70	25.7	54.66	70	29.2	67.69
			77	38.9	93.96	77	43.60	98.73	77	26.3	61.54	77	30.1	65.66	77	34.2	81.31
			84	44.9	111.17	84	50.30	116.75	84	30.3	72.67	84	34.8	77.81	84	39.5	96.27
			91	51.2	129.86	91	57.20	136.01	91	34.7	85.26	91	39.7	90.94	91	45.1	112.60
			98	57.6	149.58	98	64.20	156.29	98	39.2	98.61	98	44.9	105.30	98	50.9	130.11
			105	64.2	170.60	105	71.30	177.62	105	43.9	113.01	105	50.3	120.71	105	56.9	148.84

Figure 11: Pig Feed & Growth Curves entry screen

Pigs Details Menu (Figure 12)

Group Details

- From the Main Menu screen, click on the Pig Details button.
- Data should be entered for each Pig Group on the site (space is available for up to 50 individual pig groups).
- Type in Group ID's into first row. These ID's should be unique identifiers known to farm staff.
- For each group, identify the piggery Unit to which the group belongs by clicking on the Unit box and selecting from the drop down list.
- For each Pig Group, click on the Pig Category box and select from the drop down list.
- Fill in the Average Number of pigs in each pig group on-site.
- Click on the Manure Management System box and select the correct MMS for each Pig Group from the drop down list.

Growth Details

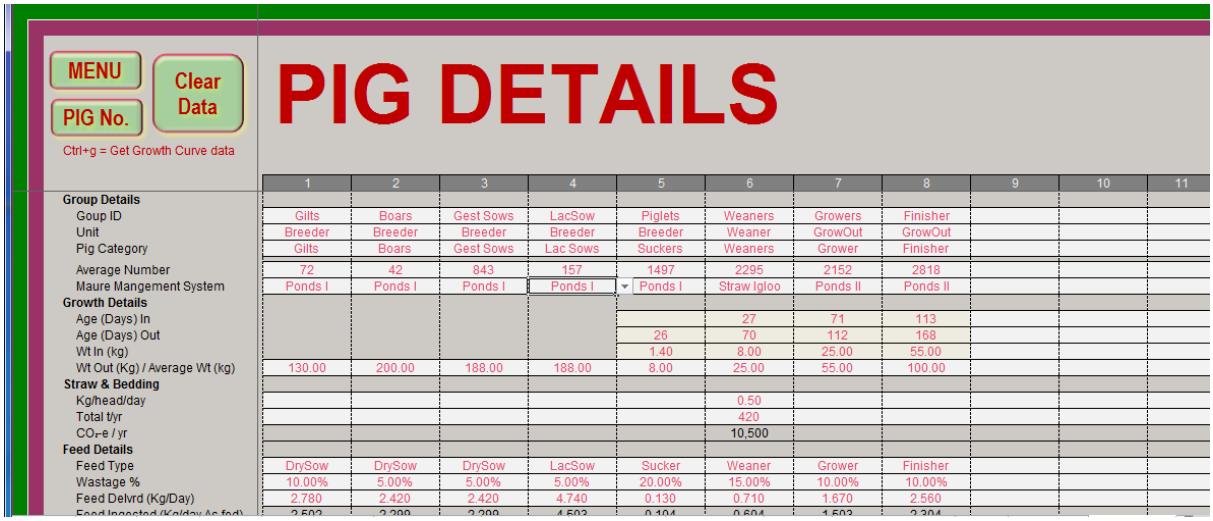
- For each Pig Group, enter the relevant Age In, Age Out , Weight In and Weight Out boxes. (Note: Ctrl +G will get Growth Curve data in lieu of entering data from farm records. Enter Age In, Age Out, Feed Type and Feed wastage - then press ctrl+g in the Feed Delrvd row - the weight and feed data will be enter automatically for the selected growth curve.)

Straw & Bedding

- For each Pig Group, enter the quantity of bedding used in deep litter systems or outdoor shelters. Quantities can be entered either as kg/head/d or total t/yr.

Feed Details

- For each Pig Group, enter the Feed Type used by clicking on the Feed Type box and selecting from the drop down list.
- For each PigGroup, enter the feed Wastage %, by clicking on the box and selecting from the drop down list.
- For each Pig Group, type in the Feed Delivered in kg from farm records. (This data will be populated automatically if Growth Curve data was chosen earlier.)
- Click Menu button to return to Main Menu.



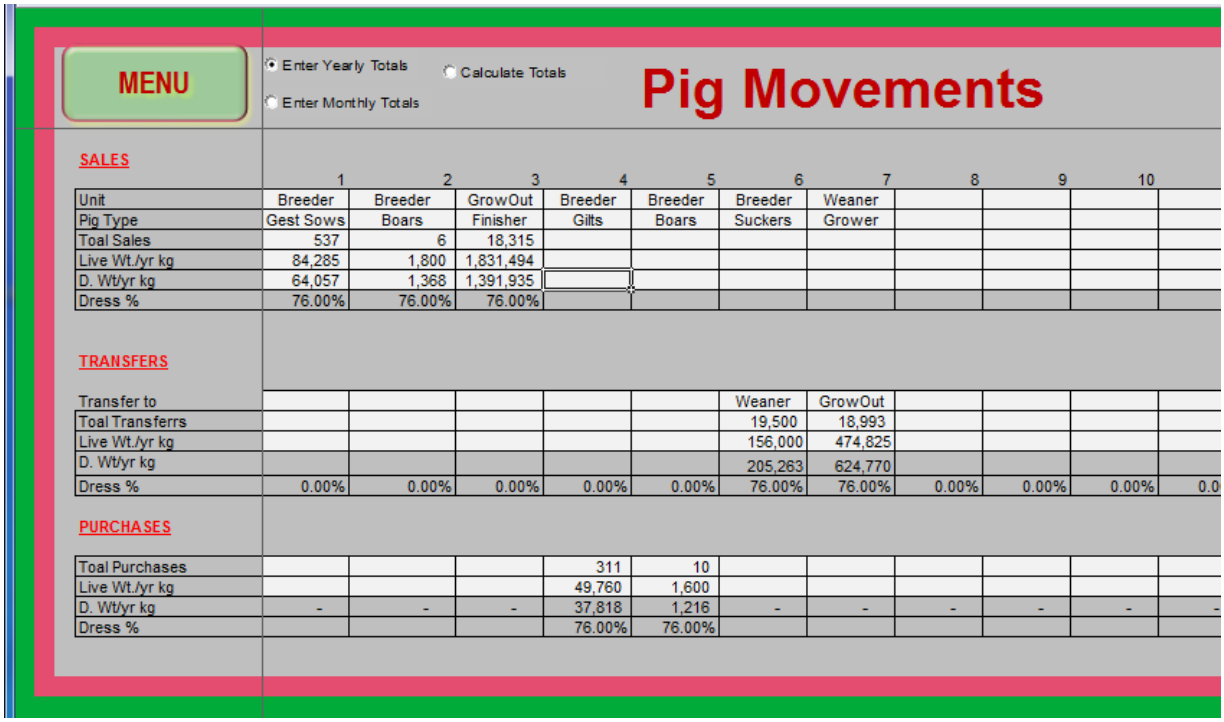
	1	2	3	4	5	6	7	8	9	10	11
Group Details											
Goup ID	Gilts	Boars	Gest Sows	LacSow	Piglets	Weaners	Growers	Finisher			
Unit	Breeder	Breeder	Breeder	Breeder	Breeder	Weaner	GrowOut	GrowOut			
Pig Category	Gilts	Boars	Gest Sows	Lac Sows	Suckers	Weaners	Grower	Finisher			
Average Number	72	42	843	157	1497	2295	2152	2818			
Maure Mangement System	Ponds I	Ponds I	Ponds I	Ponds I	Ponds I	Straw Igloo	Ponds II	Ponds II			
Growth Details											
Age (Days) In						27	71	113			
Age (Days) Out					26	70	112	168			
Wt In (kg)					1.40	8.00	25.00	55.00			
Wt Out (Kg) / Average Wt (kg)	130.00	200.00	188.00	188.00	8.00	25.00	55.00	100.00			
Straw & Bedding											
Kg/head/day						0.50					
Total t/yr						420					
CO_2-e / yr						10,500					
Feed Details											
Feed Type	DrySow	DrySow	DrySow	LacSow	Sucker	Weaner	Grower	Finisher			
Wastage %	10.00%	5.00%	5.00%	5.00%	20.00%	15.00%	10.00%	10.00%			
Feed Delvrd (Kg/Day)	2.780	2.420	2.420	4.740	0.130	0.710	1.670	2.560			

Figure 12: Pig Details entry screen

PigMovements Menu (Figures 13, 14 & 15)

- From the Main Menu screen, click on the Pig Movements button.
- Choose entry type by clicking Enter Yearly Totals (Figure 13), Enter Monthly Totals (Figure 14) or Calculate Totals from weekly data (Figure 15).

  Sales
  - In each column, piggery Units and their associated Pig Types can be selected by clicking on the relevant boxes and choosing from the drop down lists.
  - From farm records, manually enter Total Sales, Livewight and Dressed Weight for each Unit and Pig Type.



	1	2	3	4	5	6	7	8	9	10	
Unit	Breeder	Breeder	GrowOut	Breeder	Breeder	Breeder	Weaner				
Pig Type	Gest Sows	Boars	Finisher	Gilts	Boars	Suckers	Grower				
Toal Sales	537	6	18,315								
Live Wt./yr kg	84,285	1,800	1,831,494								
D. Wt/yr kg	64,057	1,368	1,391,935								
Dress %	76.00%	76.00%	76.00%								
TRANSFERS											
Transfer to						Weaner	GrowOut				
Toal Transferrs						19,500	18,993				
Live Wt./yr kg						156,000	474,825				
D. Wt/yr kg						205,263	624,770				
Dress %	0.00%	0.00%	0.00%	0.00%	0.00%	76.00%	76.00%	0.00%	0.00%	0.00%	0.0
PURCHASES											
Toal Purchases				311	10						
Live Wt./yr kg				49,760	1,600						
D. Wt/yr kg	-	-	-	37,818	1,216	-	-	-	-	-	-
Dress %				76.00%	76.00%						

Figure 13: Yearly Movements entry screen

Transfers

- When pigs are transferred between different piggery Units on the site, for each of the Units & Pig Types in each column, click on the Tansfers To box below and select a Unit to where the pigs are moving from the the drop down list.
- Enter the annual Total Transfers and their Total Live Weight in kg.

Purchases

- For each of the Unit and PigType columns, if there any purchases, then annual Total Purchases and total Live Weights should be entered.

Similar methods are used to enter monthly data (Figure 14) or weekly data (Figure 15).

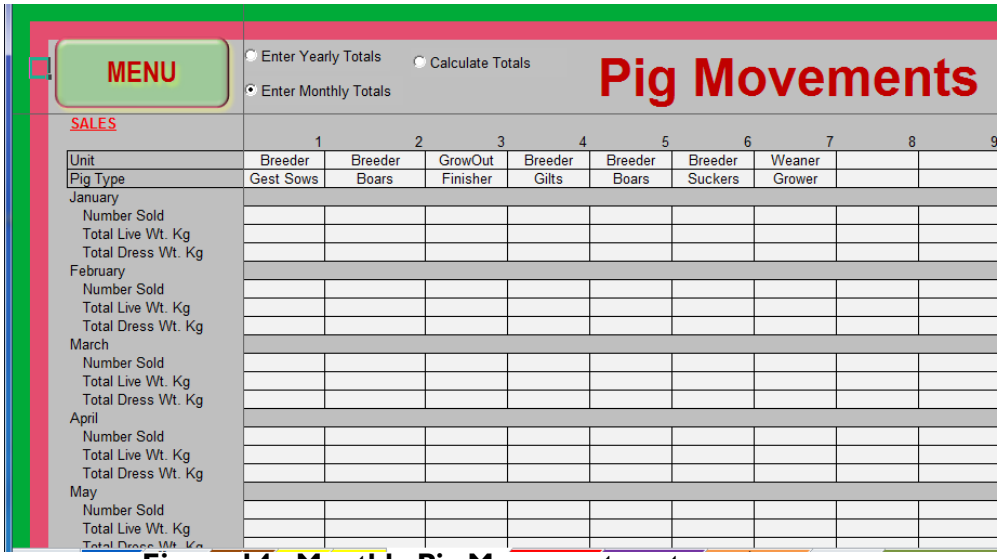


Figure 14: Monthly Pig Movements entry screen

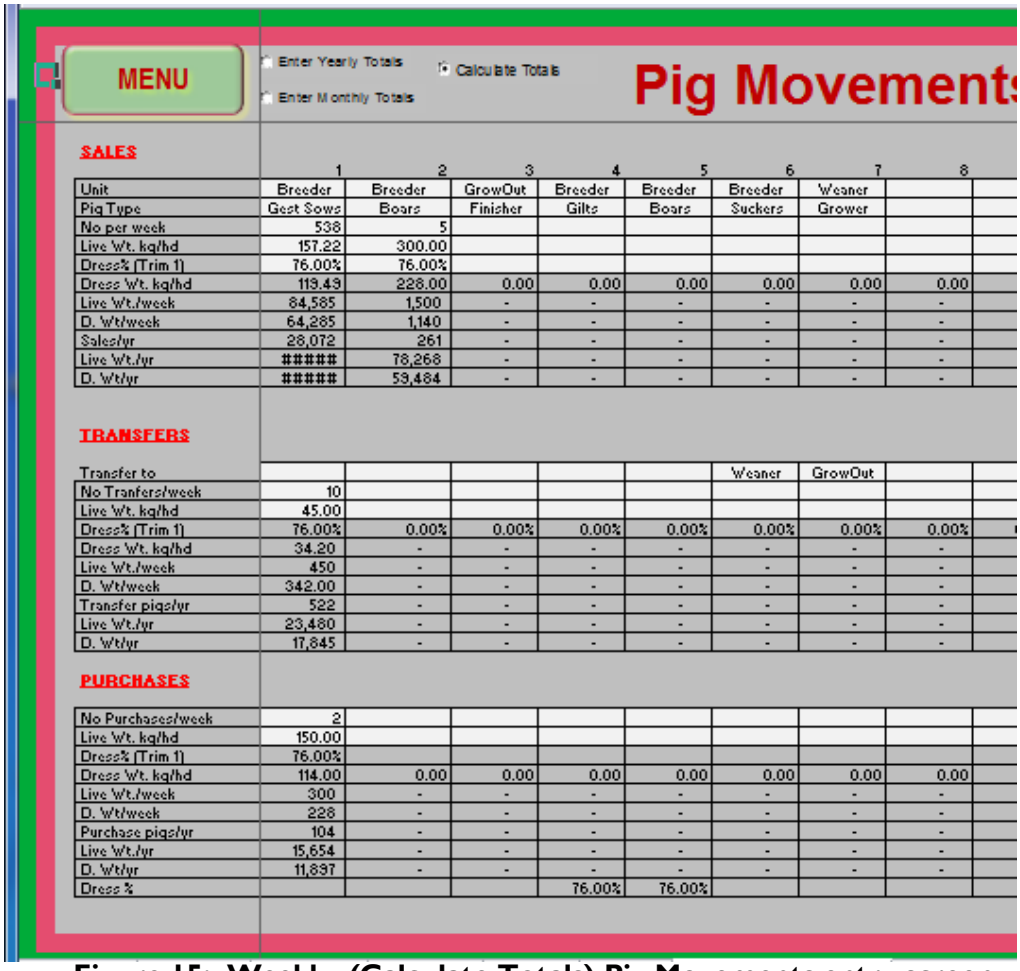
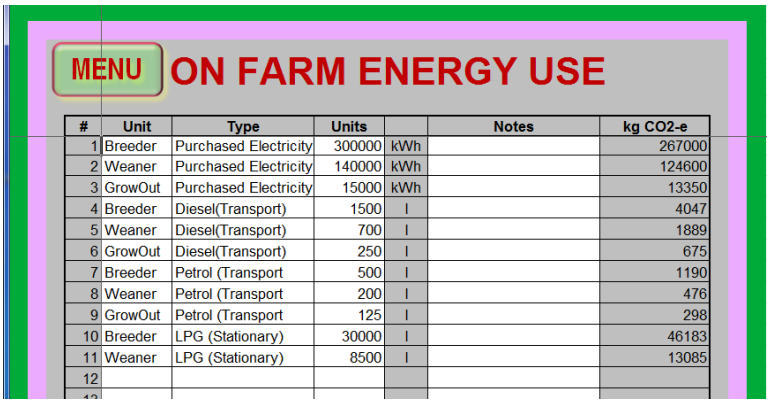


Figure 15: Weekly (Calculate Totals) Pig Movements entry screen

- Click Menu button to return to Main Menu.

Energy Use Menu (Figure 16)

- From the Main Menu screen, click on the Energy Use button.
- For each piggery Unit selected from the drop down list, select an energy type from the drop down list and manually enter the relevant annual consumption in units of kWh or litres obtained from farm records.
- Click Menu button to return to Main Menu.



#	Unit	Type	Units		Notes	kg CO2-e
1	Breeder	Purchased Electricity	300000	kWh		267000
2	Weaner	Purchased Electricity	140000	kWh		124600
3	GrowOut	Purchased Electricity	15000	kWh		13350
4	Breeder	Diesel(Transport)	1500	l		4047
5	Weaner	Diesel(Transport)	700	l		1889
6	GrowOut	Diesel(Transport)	250	l		675
7	Breeder	Petrol (Transport	500	l		1190
8	Weaner	Petrol (Transport	200	l		476
9	GrowOut	Petrol (Transport	125	l		298
10	Breeder	LPG (Stationary)	30000	l		46183
11	Weaner	LPG (Stationary)	8500	l		13085
12						

Figure 16: Energy Use entry screen

Offsets Menu (Figure 17)

- From the Main Menu screen, click on the Offsets button.
- In future, if offset methods are permitted by the Australian government to be used to offset piggery emissions, annual figures should be derived from other sources and manually entered in this table for each piggery Unit. Examples may be 'tree carbon', 'soil carbon', 'purchased carbon credits' etc expressed as kg CO_2-e/yr for each piggery Unit.
- Click Menu button to return to Main Menu.

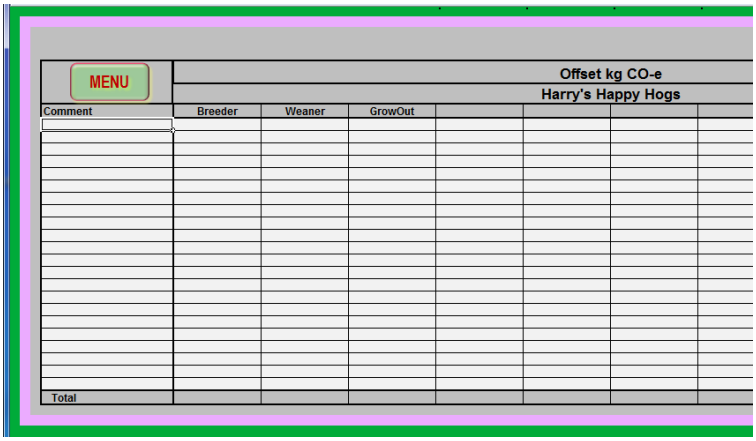
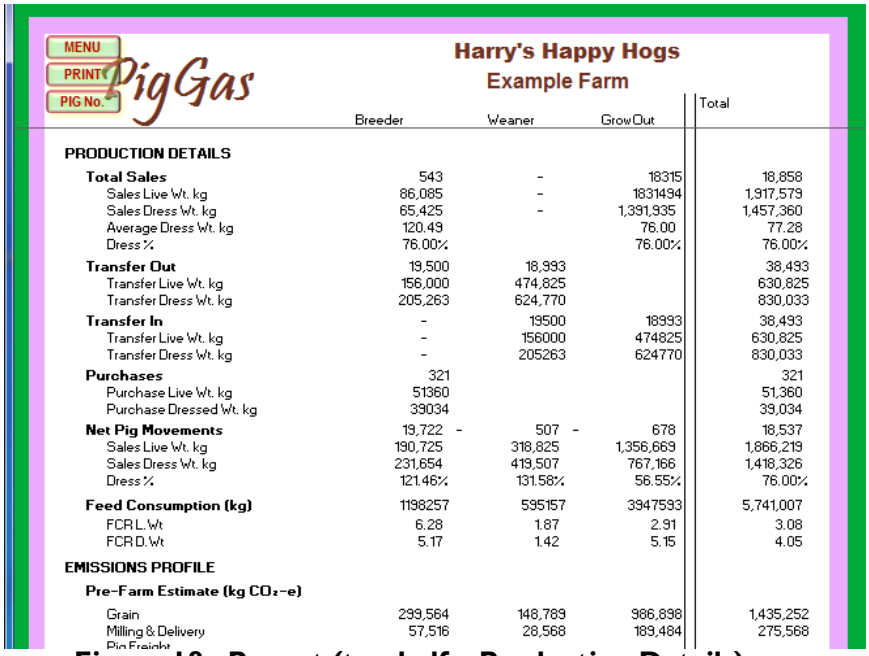


Figure 17: Offsets entry screen

Reports Menu (Figures 18 & 19)

- From the Main Menu screen, click on the Reports button.
- PigGas performs its calculations and presents the Report as shown in combined Figures 18 & 19.
- The Report can be printed by clicking the Print button.
- Click Menu button to return to Main Menu.



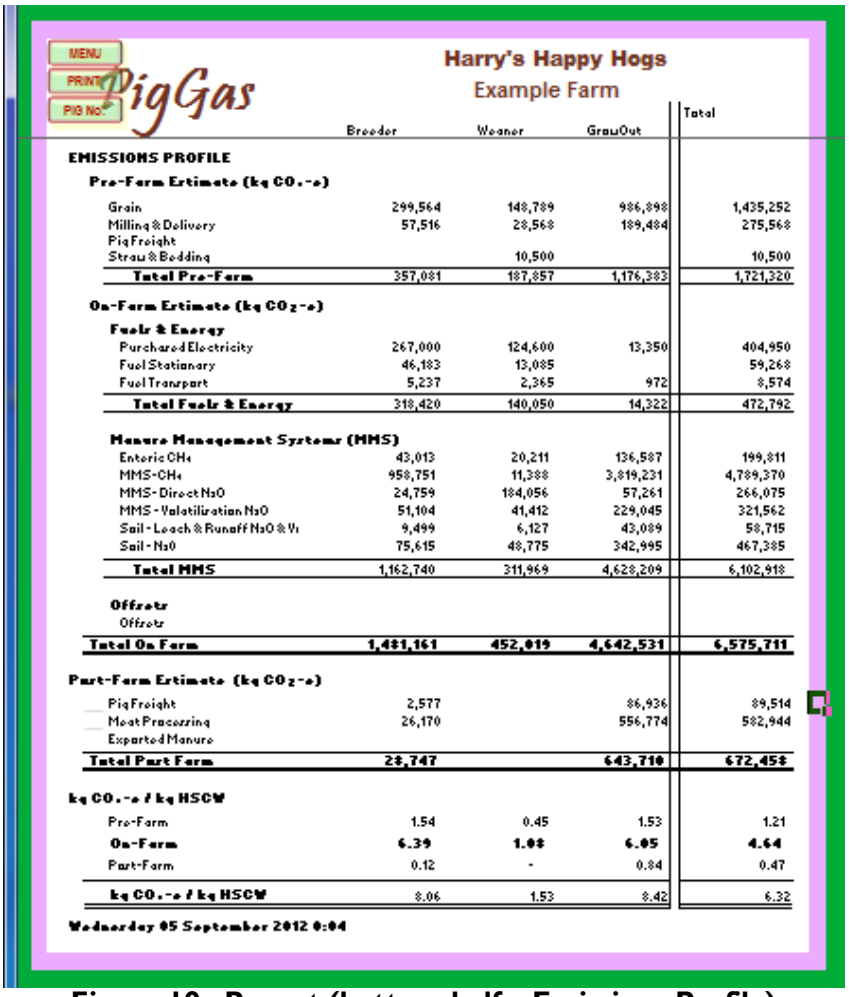
MENU
PRINT
PIG No.

PigGas

Harry's Happy Hogs
Example Farm

	Breeder	Weaner	GrowOut	Total
PRODUCTION DETAILS				
Total Sales	543	-	18315	18,858
Sales Live Wt. kg	86,085	-	1831494	1,917,579
Sales Dress Wt. kg	65,425	-	1,391,935	1,457,360
Average Dress Wt. kg	120.49		76.00	77.28
Dress %	76.00%		76.00%	76.00%
Transfer Out	19,500	18,993		38,493
Transfer Live Wt. kg	156,000	474,825		630,825
Transfer Dress Wt. kg	205,263	624,770		830,033
Transfer In	-	19500	18993	38,493
Transfer Live Wt. kg	-	156000	474825	630,825
Transfer Dress Wt. kg	-	205263	624770	830,033
Purchases	321			321
Purchase Live Wt. kg	51360			51,360
Purchase Dressed Wt. kg	39034			39,034
Net Pig Movements	19,722 -	507 -	678	18,537
Sales Live Wt. kg	190,725	318,825	1,356,669	1,866,219
Sales Dress Wt. kg	231,654	419,507	767,166	1,418,326
Dress %	121.46%	131.58%	56.55%	76.00%
Feed Consumption (kg)	1198257	595157	3947593	5,741,007
FCR L.Wt	6.28	1.87	2.91	3.08
FCR D.Wt	5.17	1.42	5.15	4.05
EMISSIONS PROFILE				
Pre-Farm Estimate (kg CO_2-e)				
Grain	299,564	148,789	986,898	1,435,252
Milling & Delivery	57,516	28,568	189,484	275,568
Pig Freight				

Figure 18: Report (top half – Production Details)



MENU
PRINT
PIG No.

PigGas

Harry's Happy Hogs
Example Farm

	Breeder	Weaner	GrowOut	Total
EMISSIONS PROFILE				
Pre-Farm Estimate (kg CO_2-e)				
Grain	299,564	148,789	986,898	1,435,252
Milling & Delivery	57,516	28,568	189,484	275,568
Pig Freight				
Straw & Bedding		10,500		10,500
Total Pre-Farm	357,081	187,857	1,176,383	1,721,320
On-Farm Estimate (kg CO_2-e)				
Fuels & Energy				
Purchased Electricity	267,000	124,600	13,350	404,950
Fuel Stationary	46,183	13,085		59,268
Fuel Transport	5,237	2,365	972	8,574
Total Fuels & Energy	318,420	140,050	14,322	472,792
Manure Management Systems (MMS)				
Enteric CH_4	43,013	20,211	136,587	199,811
MMS-CH_4	958,751	11,388	3,819,231	4,789,370
MMS-Direct N_2O	24,759	184,056	57,261	266,075
MMS-Volatilisation N_2O	51,104	41,412	229,045	321,562
Soil-Leach & Runoff N_2O & Vi	9,499	6,127	43,089	58,715
Soil-N_2O	75,615	48,775	342,995	467,385
Total MMS	1,162,740	311,969	4,628,209	6,102,918
Offsets				
Offsets				
Total On Farm	**1,481,161**	**452,019**	**4,642,531**	**6,575,711**
Part-Farm Estimate (kg CO_2-e)				
Pig Freight	2,577		86,936	89,514
Meat Processing	26,170		556,774	582,944
Exported Manure				
Total Part Farm	**28,747**		**643,710**	**672,458**
kg CO_2-e / kg HSCW				
Pre-Farm	1.54	0.45	1.53	1.21
On-Farm	**6.39**	**1.08**	**6.05**	**4.64**
Part-Farm	0.12	-	0.84	0.47
kg CO_2-e / kg HSCW	8.06	1.53	8.42	6.32

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Figure 19: Report (bottom half – Emissions Profile)

Scenario Graphic Menu (Figure 20)

- From the Main Menu screen, click on the Scenario Graphic button.
- Emissions in kgCO2-e and Emissions Intensities in kg CO2-e / kg HSCW are reported in each box representing an emissions source on the piggery. Pre-Farm, On-Farm and Post-Farm emissions are shown.
- Baseline emissions can be saved by clicking Copy To Baseline button in the upper right hand corner. A change scenario can then be modelled by changing relevant input data by again following the menus and finishing by viewing and printing a revised Report and a Scenario Graphic containing both the Baseline data and the Scenario emissions data and graphs.
- The Scenario Graphic can be printed by clicking on the Print button.
- Click Menu button to return to Main Menu.

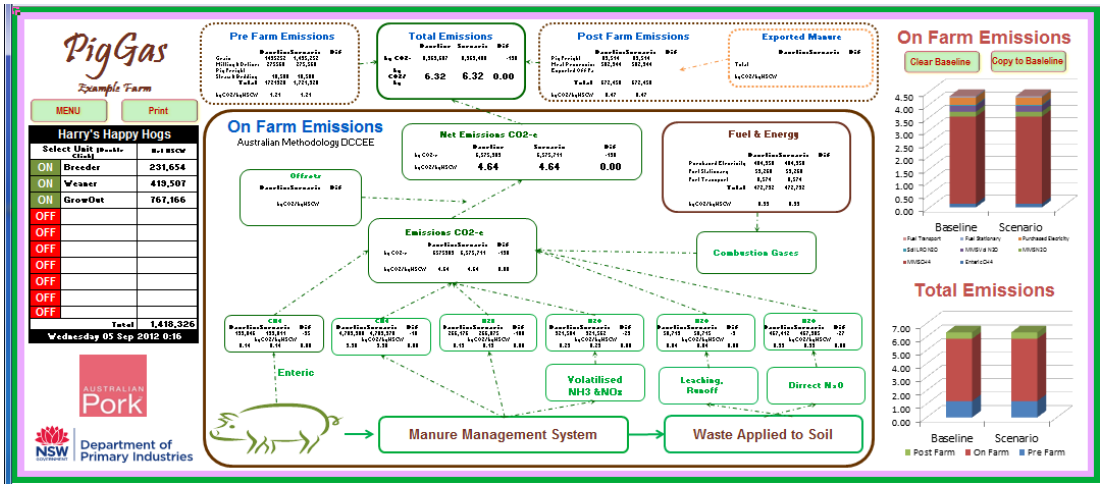

Figure 20: Scenario Graphic screen

Note: Ways to reduce piggery emissions

- reduce energy used in piggery operations;
- reduce enteric methane emissions by increasing feeding efficiency and growth rates;
- reduce methane and nitrous oxide emissions from manure management systems by changing solids separation and waste treatment options;
- reduce nitrous oxide emissions resulting from soil application of manure and effluent by changing manure management system and by changing method of soil application (e.g., direct application) and by exporting a percentage of manure or effluent off-site.

Help Menu

- From the Main Menu, click on the Help button in the bottom right hand corner to display a Help Map for PigGas.
- From within any PigGas Menu, Click on the Help sign.
- Click on the pink boxes to enlarge the Help detail for each Menu screen.
- To exit Help, click on the green Return to Data Entry arrow. This will return you to the Menu entry screen you are currently seeking Help on.
- Further Help items will be added in future, based on user feedback.

Saving and Closing Menus

- Click the Save button in the bottom right hand corner of the Main Menu to save over currently opened spreadsheet file.
- Click on the Save As New Name button to save your current changes to a new file name in your chosen directory location.
- Click on the Close button to close the spreadsheet. This bring up the normal Excel menu for exiting files (Save, Don't Save or Cancel buttons).

Conclusion

The PigGas Calculator (PigGas) was developed as a *Microsoft Excel 2010* spreadsheet for use by piggery owners, managers and advisers to estimate greenhouse gas emissions from their enterprise. PigGas follows the Australian methodology for the estimation of greenhouse gas emissions, but allows fine-tuning to the individual piggery enterprise level.

PigGas is freely available by downloading from the websites of NSW Department of Primary Industries (www.dpi.nsw.gov.au/agriculture/livestock/pigs) and Australian Pork Limited (www.australianpork.com.au).

PigGas is a useful tool to estimate piggery enterprise baseline emissions and can be used to model change scenarios and plan potential emissions reductions.

References

Australian Farm Institute (2009) FarmGAS calculator: final report and case studies. Research Report, August 2009. Australian Farm Institute, Surry Hills NSW. ISBN 9780980691238.

Tucker, R.W., McGahan, E.J., Galloway, .J.L and O'Keefe, M.F. (2010) National Environmental Guidelines for Piggeries, 2nd Edition (Revised 2011) APL Project 2231, Australian Pork Limited, ACT.

Australian Pork Limited (2008) Sources of Greenhouse Gas Emissions in the Pork Life Cycle – Snapshot. APL Factsheet, Dec 2008.

Department of Climate Change and Energy Efficiency (2011a) National Greenhouse Accounts Factors. Department of Climate Change and Energy Efficiency, Commonwealth of Australia, Canberra ACT, July 2011. ISBN: 978-1-921299-86-5

Department of Climate Change and Energy Efficiency (2011b) Carbon Farming Initiative: Methodology for the destruction of methane generated from manure in piggeries. Approved by Domestic Offsets Integrity Committee, September 2011. http://www.climatechange.gov.au/government/submissions/closed-consultations/carbon-farming-initiative/~/media/government/initiatives/cfi/methodology-development/methodologies-under-consideration/CFI-MethanePiggeriesMethodology-20111205-PDF.pdf

Department of Climate Change and Energy Efficiency (2012) Australian National Greenhouse Accounts - National Inventory Report 2010 Volume 1. The Australian Government Submission to the UN Framework Convention on Climate Change April 2012. Department of Climate Change and Energy Efficiency, Commonwealth of Australia, Canberra ACT, April 2012. ISBN: 978-1-922003-28-7.

Casey, K.D., McGahan, E.J., Atzeni, M.A., Gardener, E.A. & Frizzo, R.E. (1996) PIGBAL: A nutrient balance model for intensive piggeries. Queensland Department of Primary Industries, Version 2.14, 10 February 2000.

Kruger, I.R., Taylor, G.A. and Ferrier, M. (1995) Effluent at Work. Australian Pig Housing Series. NSW Agriculture. ISBN 0 7305 6741 9.

Kruger,I.R., Mills, G.W. & Madden, P.F. (2013) PigGas - Pork Industry Greenhouse Gas Calculator and Case Studies. Final Report APL Project 2009/1011.335, January 2013, Australian Pork Limited, ACT.

Wiedemann, Stephen, McGahan, Eugene, Grist, Shelly and Grant, Tim (2010) Environmental Assessment of Two Pork Supply Chains Using Life Cycle Assessment. RIRDC Publication No 09/176, RIRDC Project No PRJ-3176 and PRJ-4519, Rural Industries Research and Development Corporation, Barton ACT. ISBN 1 74151 973 X.

Disclaimer *The information contained in this publication is based on knowledge and understanding at the time of writing (September 2012). However, because of advances in knowledge, users are reminded of the need to ensure that the information upon which they rely is up to date and to check the currency of the information with the appropriate officer of the Department of Primary Industries or the user's independent adviser.*

Appendix 2 - Piggery GHG Emissions Case Studies Using PigGas Calculator

Case Study 1: 1,070 Sow, Farrow to Finish, Conventional Piggery, South West Slopes NSW

Production Details

This is a large family owned conventional piggery, with breeding and growing pigs on one site in seven naturally ventilated sheds. Most of the pigs are sold as heavy finishers for export markets at 115 kg live weight.

Feed Consumption

Some feed grain is grown on-site with majority of feed purchased off-site and milled off-site. Normal piggery cereal-based feedstuffs are supplemented with waste by-products from other industries with total feed consumed at 7,121 t/yr.

Sales/Transfers

21,956 pigs/yr are sold with a total dressed weight of 1,964 t/yr.

Waste Management Systems

Manure is automatically flushed from each shed in underfloor drains to a large collection sump. From there, effluent is pumped to three Sedimentation and Evaporation Ponds (SEPS). Effluent decomposes anaerobically in the SEPS which are long narrow shallow ponds designed to be dried out each year to collect sludge solids for land spreading. The overflow from the SEPS is pumped to holding anaerobic ponds.

Manure Reuse Systems

Effluent from the anaerobic holding ponds is regularly irrigated to large areas of pastures for sheep and cattle grazing and to cropping areas. Total property area is 3,950 ha with about 450 hectares cropped with triticale, barley, lupins and silage canola.

Annual Emissions Profile

Emissions	Current Emissions Baseline (kg CO_2-e/yr)	Reduction Scenario (kg CO_2-e/yr)
Pre-farm		
Grain	1,780,292	1,580,826
Milling & delivery	341,816	303,519
Pig freight		
Straw & bedding		
Total Pre-farm	***2,122,109***	***1,884,344***
On-farm		
Fuels & energy		
Purchased electricity	551,159	0
Fuel - stationary	56,873	0
Fuel - transport	4,209	4,209
Enteric CH_4	233,229	233,276
Manure management		
MMS CH_4	10,970,269	797,866
MMS – direct N_2O	62,568	52,135
MMS – Atmos. deposition N_2O	250,274	0
Waste applied to soil		
Soil – direct N_2O	374,785	520,830
Soil – leaching & runoff N_2O	47,082	65,429
Total On-farm	***12,550,449***	***1,673,745***
Post-farm		
Pig freight	144,398	144,398
Meat processing	785,725	785,725
Exported manure		
Total Post-farm	***930,123***	***930,123***
Dressed weight sold - HSCW (kg/yr)	**1,964,312**	**1,964,312**
Carbon footprint	**(kg CO_2-e / kg HSCW)**	**(kg CO_2-e / kg HSCW)**
Pre-farm	1.08	0.96
On-farm	**6.39**	**0.85**
Post-farm	0.47	0.47
Total	**7.94**	**2.28**

Emission Reduction Scenario

Like most conventional piggeries with anaerobic ponds, the majority of emissions on this piggery come from pond methane. Higher than normal levels of feed wastage contributed to pond loading rates and methane emissions.

There are two options to reduce emissions. The first is to reduce feed wastage of the grower pigs (25% to 5%) and of the finisher pigs and gilts (20% to 5%) by repairing and adjusting feeders. The second is to cover the pond to capture and reuse methane for on-site energy replacement.

This scenario (see table above) **reduced on-farm emissions from 12,550,449 kg/yr to 1,673,745 kg/yr (87% reduction) and reduced kgCO_2-e/kg HSCW from 6.39 to 0.85.** About one third of this reduction is due to reducing feed wastage.

The piggery owners are currently obtaining approvals to build and operate a covered anaerobic pond using captured methane to generate electricity and capture waste heat from the engines. This will replace all electricity and LPG used on-site. Excess electricity will be fed into the state grid. The owners have also successfully repaired and modified feeders to address the feed wastage problem.

Case Study 2: 28,030 Pig, Wean to Finish, Conventional Piggery, Central Vic

Pond cover in foreground, flare in centre.

Production Details

This piggery grows pigs from weaning to finishing in old conventional buildings. The weaner pigs are in mechanically ventilated and heated in rooms, while the growers and finishers are in open naturally ventilated sheds. The site consists of two separate Units, 1 & 2. Newly weaned pigs at 21 days old are transferred to Unit 1 from a 3,250 sow breeding site 120 km away. At 119 days old, they are then transferred to Unit 2 to finish growing to sale weight at 162 days old.

Feed Consumption

Feed grains are purchased off-site. Pig feed is mixed and milled on-site at Unit 2. Total feed consumed in Units 1 and 2 is 17,907 t/yr.

Sales/Transfers

71,957 weaner pigs/yr are transferred in to the site (Unit 1). Finishers sold from Unit 2 have a total dressed weight of 5,224 t/yr.

Waste Management Systems

All manure is collected in underfloor drains and flushed from the sheds to a large concrete sump. The effluent is pumped to a run-down screen to remove course solids before flowing to a covered anaerobic pond where methane is captured and flared. Separated solids are exported off-site. This system was installed primarily for regulatory purposes to eliminate pond odour.

Manure Reuse Systems

Treated effluent is applied to approximately 100 ha of irrigated cropping systems. Separated manure solids are sold off-site for land application.

Annual Emissions Profile

Emissions	Original Emissions (kg CO_2-e/yr)	Current Baseline Emissions	Reduction Scenario
Pre-farm			
Grain	4,476,846	4,476,846	4,476,846
Milling & delivery	859,555	859,555	859,555
Pig freight	20,188	20,188	20,188
Straw & bedding	0	0	0
Total Pre-farm	***5,356,589***	***5,356,589***	***5,356,589***
On-farm			
Fuels & energy			
Purchased electricity	995,068	995,068	0
Fuel – stationary LPG	230,182	230,182	0
Fuel - transport	183,811	183,811	183,811
Enteric CH_4	679,667	679,667	679,667
Manure management			
MMS CH_4	13,646,056	1,288,794	1,288,794
MMS – direct N_2O	154,990	147,240	147,240
MMS – Atmos. deposition N_2O	619,959	0	0
Waste applied to soil			
Soil – direct N_2O	929,389	1,470,931	1,470,931
Soil – leaching & runoff N_2O	116,629	184,786	184,786
Total On-farm	***17,554,751***	***5,180,480***	***3,955,230***
Post-farm			
Pig freight	76,685	76,685	76,685
Meat processing	2,089,726	2,089,726	2,089,726
Exported manure	0	270,210	270,210
Total Post-farm	***2,166,412***	***2,436,622***	***2,436,622***
Dressed weight sold - HSCW (kg/yr)	**5,224,311**	**5,224,311**	**5,224,311**
Carbon footprint	**(kg CO_2-e / kg**	**(kg CO_2-e / kg HSCW)**	**(kg CO_2-e / kg**
Pre-farm	1.03	1.03	1.03
On-farm	**3.36**	**0.99**	**0.76**
Post-farm	0.41	0.47	0.47
Total	**4.80**	**2.48**	**2.25**

Emission Reduction Scenario

The only option to reduce greenhouse emissions any further is to utilise the pond methane instead of flaring it. Electricity generation and heat recovery from the engine burning methane will replace all on-site electricity and LPG usage and feed excess electricity to the state grid. Three scenarios were modelled (see table above). Firstly, the 'Original Emissions' prior to covering the pond or screening solids yielded **on-farm emissions of 17,554,751 kg CO_2-e /yr or 3.36 kgCO_2-e/kg HSCW.**

Secondly, the 'Current Baseline Emissions' with solids screening, pond covering and methane flaring **reduced on-farm emissions from 17,554,751 kg CO_2-e /yr to 5,180,480 kg CO_2-e /yr (70% reduction) and reduced kgCO_2-e/kg HSCW from 3.36 to 0.99.**

Thirdly, adding on-site electricity generation and heat recovery to eliminate on-farm electricity and LPG) **reduced on-farm emissions from 5,180,480 kg CO_2-e /yr to 3,955,230 kg CO_2-e /yr (24% reduction) and reduced kgCO_2-e/kg HSCW from 0.99 to 0.76.**

The owners of the piggery are currently budgeting for the final scenario change.

Case Study 3: 13,700 Weaner Piggery on Deep Litter (Straw), South East Qld

Production Details

This weaner piggery site is one of three sites in a multisite operation comprising breeder, weaner and finisher units. Weaner pigs are grown on this site from 3 weeks (6 kg) to 12 weeks (34 kg) old. Weaners are housed on deep litter bedding (straw) in large groups of approximately 500 or 1,000 weaners in a total of 26 sheds. Sheds are plastic tunnel type, fitted with mechanical tunnel ventilation. The site is isolated from the state electricity grid and runs diesel powered generators on-site to supply power.

Feed Consumption

Pig feed is mixed and milled by the company off-site. Total feed consumed is 5,296 t/yr.

Sales/Transfers

79,352 pigs/yr are transferred off-site to the finishing unit. For the purposes of calculating emissions intensity, the estimated total dressed weight of the transferred pigs is 2,198 t/yr.

Waste Management System – deep litter

Manure Reuse Systems

Spent litter (manure plus straw) from the sheds is composted and spread as fertiliser on dryland summer and winter cropping paddocks, growing sorghum, chickpeas, wheat, barley and field peas. Thousands of hectares are available in the cropping enterprises for manure reuse.

Annual Emissions Profile

Emissions	**Current Emissions Baseline (kg CO_2-e/yr)**	**Reduction Scenario (kg CO_2-e/yr)**
Pre-farm		
Grain	1,323,998	1,323,998
Milling & delivery	254,208	254,208
Pig freight	24,837	24,837
Straw & bedding	35,750	0
Total Pre-farm	***1,638,793***	***1,603,043***
On-farm		
Fuels & energy		
Purchased electricity	0	0
Fuel - stationary	705,014	0
Fuel - transport	3,570	3,570
Enteric CH_4	197,661	1,197,661
Manure management		
MMS CH_4	69,316	462,104
MMS – direct N_2O	947,399	47,370
MMS – Atmos. deposition N_2O	213,165	0
Waste applied to soil		
Soil – direct N_2O	251,061	473,226
Soil – leaching & runoff N_2O	31,539	59,449
Total On-farm	***2,418,724***	***1,243,380***
Post-farm		
Pig freight	630	630
Meat processing	0	0
Exported manure	0	0
Total Post-farm	***630***	***630***
Dressed weight sold - HSCW (kg/yr)	**2,198,014**	**2,198,014**
Carbon footprint	**(kg CO_2-e / kg HSCW)**	**(kg CO_2-e / kg HSCW)**
Pre-farm	0.75	0.73
On-farm	**1.10**	**0.57**
Post-farm	0.00	0.00
Total	**1.85**	**1.30**

Emission Reduction Scenario

The piggery owners are contemplating the feasibility of converting the floors of this deep litter piggery to a fully flushed effluent system. Effluent from this weaner unit together with effluent from a nearby finishing unit would be combined into a covered anaerobic pond capturing methane. Methane would be used to replace diesel fuel in the existing engine driven electricity generators on each site.

This scenario (see Table above) **reduced on-farm emissions from 2,418,724 kg/yr to 1,243,380 kg/yr (49% reduction), and reduced kgCO_2-e/kg HSCW from 1.10 to 0.57.**

Case Study 4: 154 Sow, Farrow to Finish, Conventional Piggery, Central West NSW

Production Details

This is a conventional, continuous flow, farrow to finish piggery, in a single large naturally ventilated shed. It is one enterprise in a typical mixed sheep, cattle and cereal cropping farm.

Feed Consumption

Grains are grown on-site and the feedstuffs milled on-site total 717 t/yr.

Sales/Transfers

2,459 pigs/yr are sold with a total dressed weight of 189 t/yr.

Waste Management Systems

Pen floors are partially slatted and effluent is contained in underfloor drains with are emptied by sluice gates without flushing. Effluent from the drains is channelled directly to an anaerobic (facultative) treatment pond. No solid separation is undertaken.

Manure Reuse Systems

Treated effluent from the anaerobic pond is regularly spray irrigated onto oat crops which are used for both hay production and grazing of sheep and cattle.

Annual Emissions Profile

Emissions	Current Emissions Baseline (kg CO_2-e/yr)	Reduction Scenario (kg CO_2-e/yr)
Pre-farm		
Grain	179,329	179,329
Milling & delivery	0	0
Pig freight	0	0
Straw & bedding	0	0
Total Pre-farm	***179,329***	***179,329***
On-farm		
Fuels & energy		
Purchased electricity	58,020	58,020
Fuel - stationary	0	0
Fuel - transport	2,071	2,071
Enteric CH_4	24,934	26,246
Manure management		
MMS CH_4	796,804	335,119
MMS – direct N_2O	6,059	29,082
MMS – Atmos. deposition N_2O	24,235	24,841
Waste applied to soil		
Soil – direct N_2O	36,292	35,456
Soil – leaching & runoff N_2O	4,559	4,454
Total On-farm	***952,974***	***515,289***
Post-farm		
Pig freight	3,981	3,981
Meat processing	75,611	75,611
Exported manure	0	0
Total Post-farm	***79,592***	***79,592***
Dressed weight sold - HSCW (kg/yr)	**189,028**	**189,028**
Carbon footprint	**(kg CO_2-e / kg HSCW)**	**(kg CO_2-e / kg HSCW)**
Pre-farm	0.95	0.95
On-farm	**5.04**	**2.73**
Post-farm	0.42	0.42
Total	**6.41**	**4.10**

Emission Reduction Scenario

There are two options for this piggery to cost effectively reduce greenhouse gas emissions. The first is to add a sedimentation basin before the anaerobic pond. This will prolong the life of the pond before costly desludging is required and provide access to 50% of manure solids prior to pond digestion. The solids can then be spread on crops and pastures to reduce fertiliser costs in the on-farm cropping enterprises.

The second is to reduce feed wastage from 10% to 5% for weaners and growers and from 15% to 5% for finishers by installing new feeders. It is assumed that pig production does not change.

This scenario (see table above) **reduced on-farm emissions from 952,974 kg/yr to 515,289 kg/yr (46% reduction) and reduced kgCO_2-e/kg HSCW from 5.04 to 2.73.**

Case Study 5: 125 Sow Piggery, Outdoor Bred, Indoor Wean to Finish on Deep Litter (Straw), South West Slopes NSW

Production Details

Gilts, dry sows and lactating sows on this piggery are kept outdoors. Sows are managed in five batches of 28 sows which are artificially inseminated every four weeks. Weaners from 21 days old are grown out in five deep litter shelters each holding 180 pigs. Finishers are sold at 88 kg live weight at 135 days old. Some weaners are sold at 18 kg live weight. Niche marketing is undertaken, including direct sales through a farmers market.

Feed Consumption

Prepared feeds totalling 831 t/yr are purchased off-site.

Sales/Transfers

2,452 pigs/yr are sold with a total dressed weight of 169 t/yr.

Waste Management Systems

Manure from outdoor sows is directly deposited to soil. Spent litter from all growing stock in 5 deep litter sheds is exported off-site. A sorting shed and a sow holding shed holding small numbers of stock drain effluent to 5,000 litre sumps. Effluent from these sumps is stored (liquid/slurry systems) and then pumped out to pasture.

Manure Reuse Systems

Sows are kept in paddocks totalling about 40 hectares on a 140 hectare mixed farm which includes saltbush-finished lamb and cereal cropping. All spent litter from sheds is exported off-site to a neighbouring grain farm in exchange for straw for use in deep litter sheds and sow shelters.

Annual Emissions Profile

Emissions	Current Emissions Baseline (kg CO_2-e/yr)	Reduction Scenario (kg CO_2-e/yr)
Pre-farm		
Grain	207,728	207,728
Milling & delivery	39,884	39,884
Pig freight	0	0
Straw & bedding	4,562	4,562
Total Pre-farm	***252,174***	***252,174***
On-farm		
Fuels & energy		
Purchased electricity	9,719	0
Fuel - stationary		0
Fuel - transport	7,868	7,868
Enteric CH_4	27,497	29,114
Manure management		
MMS CH_4	37,642	34,828
MMS – direct N_2O	103,242	103,242
MMS – Atmos. deposition N_2O	27,144	27,144
Waste applied to soil		
Soil – direct N_2O	25,663	25,663
Soil – leaching & runoff N_2O	3,224	3,224
Total On-farm	***241,998***	***231,083***
Post-farm		
Pig freight	14,746	14,746
Meat processing	67,490	67,490
Exported manure	30,655	30,655
Total Post-farm	***112,891***	***112,891***
Dressed weight sold - HSCW (kg/yr)	**168,725**	**168,725**
Carbon footprint	**(kg CO_2-e / kg HSCW)**	**(kg CO_2-e / kg HSCW)**
Pre-farm	1.49	1.49
On-farm	**1.43**	**1.37**
Post-farm	0.67	0.67
Total	**3.60**	**3.53**

Emission Reduction Scenario

Because the sows directly deposit manure to soil, and all spent litter is exported off-site rather than spread on-farm, there are no opportunities to reduce manure management systems emissions. There are only two remaining options to reduce emissions. Recently installed solar panels are generating 50% more power than used on-farm. The first option, therefore, is to model the piggery with zero electricity usage. The second option is to reduce feed wastage by 5% in the deep litter shelters for all weaners, growers and finishers, by adjusting feeders or installing new feeders.

This scenario (see table above) **reduced on-farm emissions from 241,998 kg/yr to 231,083 kg/yr (5% reduction) and reduced kgCO_2-e/kg HSCW from 1.43 to 1.37.**

Case Study 6: 48 Sow, Farrow to Pork, Free Range Piggery, Sydney Basin NSW

Production Details

All pigs remain outdoors their whole lives. Piglets stay with groups of about 12 lactating sows for seven weeks until weaning. Dry sows are run as a large group and are used to eat the remnant forage and root matter of previously harvested crops. Likewise, growers are run in large groups of about 90 from weaning to sale. Some young pigs are sold at 12 kg, 50 kg dressed weight for specialised markets, with the majority of porkers sold at about 70 kg dressed weight for niche marketing through butchers, restaurants and a farmers market. Dressed pig meat returns 3.5 to 4 times average industry prices. Normal types and quantities of purchased pig feed rations are used since foraging provides a small proportion of the pigs' whole diet.

Feed Consumption

Pig feeds totalling 204 t/yr are purchased off-site.

Sales/Transfers

746 pigs/yr are sold with a total dressed weight of 32 t/yr.

Waste Management Systems

Manure from all pig groups is deposited and daily spread by pigs outdoors. The dry sows and gilts completely turn over the sandy loam soil to a depth of 150-200 mm while manuring the soil for the next crop. The ground is then easily prepared for planting the next crop. The grower groups are rotated onto rested paddocks to clean up weeds and also onto cereals grown for pig foraging and hay production before planting a rotational organic cash crop.

Manure Reuse Systems

The free range piggery is a necessary fertiliser/tillage component of the 42 hectare mixed organic farm rotating pigs, irrigated sweet corn, forage cereals, kale, potatoes, melons, pumpkins and garlic.

Annual Emissions Profile

Emissions	**Current Emissions Baseline (kg CO_2-e/yr)**	**Reduction Scenario (kg CO_2-e/yr)**
Pre-farm		
Grain	51,098	50,796
Milling & delivery	9,811	9,753
Pig freight	0	0
Straw & bedding	590	590
Total Pre-farm	***61,499***	***61,139***
On-farm		
Fuels & energy		
Purchased electricity	1,285	1,285
Fuel - stationary	0	0
Fuel - transport	2,214	2,214
Enteric CH_4	6,766	7,040
Manure management		
MMS CH_4	1,775	1,290
MMS – direct N_2O	0	0
MMS – Atmos. deposition N_2O	1,701	1,421
Waste applied to soil		
Soil – direct N_2O	22,600	18,878
Soil – leaching & runoff N_2O	2,839	2,372
Total On-farm	***39,180***	***34,500***
Post-farm		
Pig freight	201	214
Meat processing	12,965	13,850
Exported manure	0	0
Total Post-farm	***13,166***	***14,063***
Dressed weight sold - HSCW (kg/yr)	**32,412**	**34,624**
Carbon footprint	**(kg CO_2-e / kg HSCW)**	**(kg CO_2-e / kg HSCW)**
Pre-farm	1.90	1.77
On-farm	**1.21**	**1.00**
Post-farm	0.41	0.41
Total	**3.51**	**3.17**

Emission Reduction Scenario

This free range piggery already has extremely low greenhouse gas emission rates. Manure is deposited directly to soils daily, eliminating the need for waste treatment systems and their associated emissions. Fuel and energy use are very low compared with conventional piggeries.

There are three possible ways for this piggery to reduce on-farm emissions. The first is to improve pig genetics to improve litter sizes by one piglet per sow place per year and improve growth rates and sales to 792 pigs/yr. The second is to use improved diet formulations to match growth potential. The third is to change feeding systems to reduce feed wastage from an estimated 20% to 10%.

This scenario (see table above) **reduced on-farm emissions from 39,180 kg/yr to 34,500 kg/yr (12% reduction), increased dressed weight from 32,412 kg/yr to 34,624 kg/yr (7% improvement) and reduced kgCO_2-e/kg HSCW from 1.21 to 1.00.**

Summary of Six Piggery Case Studies

Summary

The Pork Industry Greenhouse Gas Calculator (PigGas) was used to calculate carbon dioxide equivalent emissions from six different types and sizes of piggeries. The results indicate a large variation (0.99 to 6.39 kg CO_2-e / kg HSCW) in on-farm greenhouse emissions depending on existing infrastructure, production and management types. Different scenarios to reduce greenhouse gas emissions were modelled yielding reductions of 5% to 87%.

Background

Six Australian piggeries representing the wide variety of sizes and types were chosen to profile and compare greenhouse gas emissions at the piggery enterprise boundary. PigGas (Kruger et al 2013) was used to calculate on-farm emissions and estimate pre-farm and post-farm emissions to yield a 'carbon footprint' for each piggery enterprise. Annual dietary, pig production, manure management, manure reuse, energy use, transport, pig sales and carcass weight data were obtained from each of the piggeries to undertake the modelling in PigGas. Figure 1 shows the PigGas boundaries and the default Australian Methodology (DCCEE 2012) emissions sources contained in PigGas. Different strategies were also modelled to reduce emissions from each piggery.

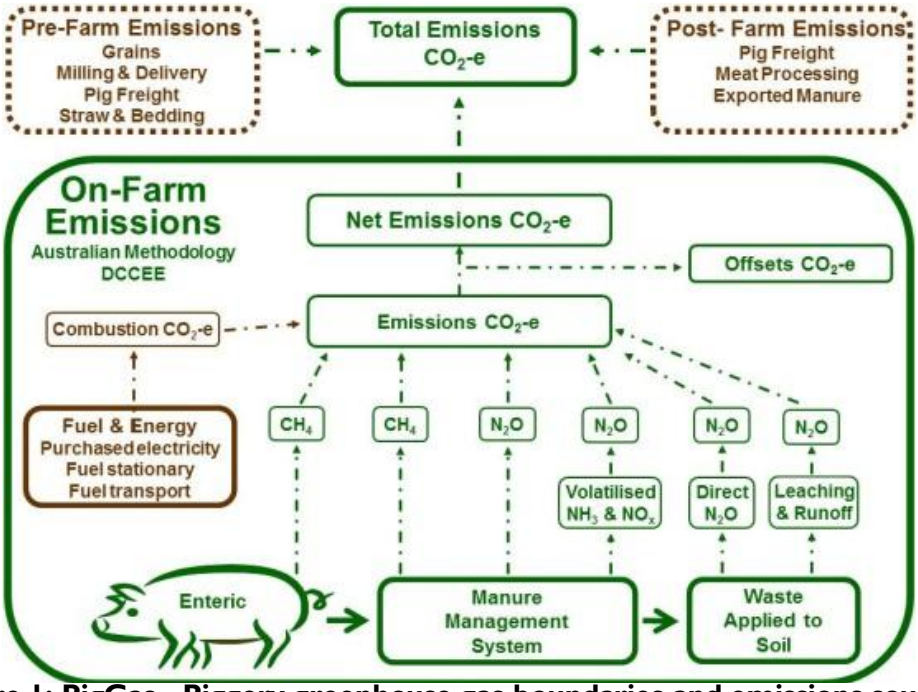

Figure 1: PigGas - Piggery greenhouse gas boundaries and emissions sources

Results

Table 1 Description of piggeries, baseline emissions and reduction scenarios

Piggery Description	**1** 1,070 sow farrow to finish conventional	**2** 28,030 pig wean to finish conventional	**3** 13,700 weaners on deep litter, tunnel vent, electricity (diesel) generation	**4** 154 sow farrow to finish conventional	**5** 125 sow outdoor bred, wean to finish on deep litter	**6** 48 sow farrow to pork free range
Manure Management System	Flushed drains, sump, SEPS, anaerobic ponds	Flushed drains, sump, screen, covered anaerobic pond, flare	Deep litter (straw)	Storage drains, facultative pond.	Sows outdoors, growers deep litter (straw)	All stock outdoors
Manure Reuse	Effluent irrigated on crops & pastures	Effluent irrigated on crops, solids exported	Spent litter spread on crops	Effluent irrigated on crops & pastures	Sows rotate on pastures, spent litter exported	All stock rotated on crops & pastures
Emissions Reduction Scenario	Add covered anaerobic pond, CH_4 capture, electricity generation, heat recovery to replace all site energy	Convert CH_4 flaring to generate electricity & engine heat recovery to replace site all site energy	Convert sheds to flushing, add covered anaerobic pond, CH_4 capture to generate electricity to replace site diesel	Add sediment'n basin before pond, reduce feed waste in growers	Install solar panels, reduce feed waste in growers	Improve genetics, growth rates & sales, improve diets, reduce feed waste all stock

Greenhouse Gas Emissions from Six Piggeries
(Reduction Scenarios in Brackets)
(kg CO_2-e / kg HSCW)

Piggery	**1**	**2**	**3**	**4**	**5**	**6**
Pre-Farm	1.08 (0.96)	1.03 (1.03)	0.75 (0.73)	0.95 (0.95)	1.49 (1.49)	1.90 (1.77)
On-Farm	**6.39**	**0.99**	**1.10**	**5.04**	**1.43**	**1.21**
Post-Farm	0.47 (0.47)	0.47 (0.47)	0.00 (0.00)	0.42 (0.42)	0.67 (0.67)	0.41 (0.41)
Total	7.95 (2.28)	2.48 (2.25)	1.85 (1.30)	6.41 (4.10)	3.60 (3.53)	3.51 (3.17)

References

Department of Climate Change and Energy Efficiency (2012) Australian National Greenhouse Accounts - National Inventory Report 2010 Volume 1. The Australian Government Submission to the UN Framework Convention on Climate Change April 2012. Department of Climate Change and Energy Efficiency, Commonwealth of Australia, Canberra ACT, April 2012. ISBN: 978-1-922003-28-7.

Kruger,IR, Mills, GW & Madden, PF (2013) PigGas - Pork Industry Greenhouse Gas Calculator and Case Studies. Final Report APL Project 2009/1011.335, January 2013, Australian Pork Limited, ACT.