Poultry management in New Zealand: production, manure management and emission estimations for the commercial chicken, turkey, duck and layer industries within New Zealand

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Report *on the*

Poultry management in New Zealand: production, manure management and emission estimations for the commercial chicken, turkey, duck and layer industries within New Zealand

15 July 2011

From the:

Poultry Industry Association of New Zealand (Inc).

and the

Egg Producers Federation of New Zealand (Inc).

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EXECUTIVE SUMMARY

This report describes the current poultry management practisces that occur in the New Zealand meat chicken, turkey meat, duck meat and layer industries in order to begin to improve the assumptions for poultry emissions estimates. Further information on poultry industry practices are required so that defaults currently used can be replaced by New Zealand specific information.

The work presented in this document encompasses (i) surveys conducted on the poultry industry which cover poultry feed and manure management practices, (ii) a review of the national and international scientific evidence on the methane and nitrous oxide emissions from poultry and (iii) an updated emissions profile from these commercial poultry sectors to be used in New Zealand's greenhouse gas inventory and for the determination of poultry specific emission factors to be used in New Zealand's Emissions Trading Scheme.

A review of the NZ and international literature suggested that the use of current IPCC (1996) default values results in emission overestimates from NZ poultry. These overestimates were due to the use of default values for volatile solids (VS), nitrogen excretion by poultry (Nex), non-poultry-specific emission factor (EF_3). Additionally, inaccuracies in nitrogen application to agricultural soils caused by not accounting for the N volatilisation loss from animal-waste management-systems also led to the above mentioned overestimates.

A NZ specific survey was performed in order to determine manure management practices from both the commercial poultry meat and layer hen industries. Additionaly, further information on situations where different poultry management regimes are followed and where different feed types are used was also included in the survey.

From the survey information and the literature review, more appropriate emission factors have been suggested for the commercial poultry industry in New Zealand and the emissions profile of these indsutries have been determined.

In order to improve the accuracy of CH_4 and N_2O emissions from poultry in NZ it is recommended that:

i) the poultry population is divided into subclasses (i.e. meat chicken, layer, duck and turkey) and the EFs of each subclass are used.

ii) the current IPCC default mean VS value of 0.10 kg VS day^{-1} is replaced with the NZ specific VS values of 0.014 kg VS day^{-1}for layers, 0.019 kg VS day^{-1} for meat chickens, 0.023 kg VS day^{-1}for ducks and 0.11 kg VS day^{-1}for turkeys.

iii) the current IPCC mean Nex default value of 0.6 kg N animal^{-1} year^{-1} is replaced with NZ specific values of 0.42 kg N animal^{-1} year^{-1}for layers, 0.39kg N animal^{-1} year^{-1} for meat chickens only. As there is no NZ Nex data for ducks and turkeys the value of 0.60 kg N animal^{-1} year^{-1} be maintained.

iv) the current non-poultry-specific EF_3 0.005 kg N_2O-N/kg for litter category birds is reduced to poultry-specific EF_3 0.001 kg N_2O-N/kg N from AWMS.

v) a conservative value of 40% N volatalisation loss ($Frac_{LossMS}$) from AWMS is included in the NIR to improve the accuracy of N application to agricultural soils.

vi) for manure N application to agricultural soils NZ specific EF_3 of 0.01 for emissions from animal excreta deposited in grazed pastures is used to calculate N_2O emissions and $Frac_{gasm}$of 0.1 and $Frac_{leach}$ of 0.07 are used to calculate gaseous and leaching losses from poultry manure applied to agricultural soils.

Based on the methodology put forward to calculate flock sizes for the commercial meat chickens, turkey and ducks, the poultry industry in 2009/2010 grew a total of 8,362,330meat chickens, 53,916 turkeys and 99,962 ducks in the calendar year. The flock size of the layer industry was based off of the information provided by Statistics New Zealand, i.e. 3,350,290 hens in lay for egg production.

The carbon dioxide equivalent methane and nitrogen oxide emissions from the meat chicken, layer, turkey and duck industries produced a total of 25,154, 13,886, 372 and 431 tonnes of CO_2 equivalent emissions, respectively.

Expert opinion was provided to comment on how the poultry management practices changed since the 1990's. The major changes provided by expert opinion included the increase in the performance of both meat chickens and layer hens due to genetics and the usage amino acids, enzymes and feed manufacturing technology to aid in the digestability of the manufactured commercial poultry feed. A meat chicken/broiler growing model (i.e. Emmans Fisher and Gous model)was also utilized to demonstrated the changes associated with feed conversion and nitrogen excretion of NZ meat chickens from 1990 to 2011.

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1 BACKGROUND

Currently default emission factors and assumptions are used in the New Zealand Greenhouse Gas (GHG) Inventory for determining emissions from the poultry industry. In 2009/2010 the Poultry Industry Association of New Zealand (PIANZ) and the Egg Producers Federation of New Zealand (EPFNZ) produced a report of the emissions estimates for the commercial chicken, non-chicken and layer industries in New Zealand (PIANZ & EPFNZ, 2010). In this report, Industry data on gross intake and digestibility of a set feeding situation was collected and used to estimate greenhouse gas emissions. Nitrogen excretion rates for this feeding situation are also assessed and emissions from both these industries were determined.

However, in order to improve the assumptions for poultry emissions estimates, further information on poultry industry practices are required so that defaults currently used can be replaced by New Zealand specific information.

The requirements of this work were to:

(i) survey the poultry industry on poultry feed and manure management practices and
(ii) review international published research and available New Zealand data

The requirements (above) would thus aid in determining:

1. the proportion of the poultry industry using different management practices
2. the proportion of manure within each management system
3. how poultry manure is managed and what proportion of manure is handled in each waste management system
4. different feeds used in the poultry industry
5. feeding regimes used i.e. which feeds are fed when and for how long
6. proportion of each feed type and regime that is used in the poultry industry
7. a breakdown of fed attributes where available (i.e. for processed feeds this data should be available) covering metabolisable energy, digestibility and protein content

1.1 Methodology

The work undertaken by PIANZ/EPFNZ involved:

1.1.1. Developing and sending a survey to poultry meat companies and commercial egg producers to collect the information outlined above.

1.1.2. Determining and assessing the breakdown of feed ingredients and feed attributes in poultry feed for the chicken, turkey and duck meat companies as well as the egg producers in New Zealand. The information requested was included in the survey[1] to PIANZ and EPFNZ members.

1.1.3. Assessing the survey data and determining the proportions of poultry feed and manure management practices utilised in the poultry industry.

[1]The survey data was collated and compiled by an independent subcontractor for EPFNZ members.

1.1.4. Conducting a review the national and international scientific evidence for methane and nitrous oxide emissions from poultry. This will include situations where different poultry management regimes are followed and where different feed types are used. The literature review will also include key factors affecting methane, nitrous oxide and ammonia emissions from poultry.

Landcare Research was subcontracted through the Poultry Industry Association of New Zealand (PIANZ) to provide information on poultry management in New Zealand to improve the assumptions for poultry emissions estimates and to replace currently used default values by country-specific information. Landcare Research also assessed the relevant emission factors within the national inventory, their uncertainty based on available New Zealand published and unpublished data. Landcare Research also examined the contribution of emissions to the New Zealand inventory in order to identify the gaps in the inventory data for the commercial polutry industry in New Zealand.

2 INTRODUCTION

The Poultry Industry Association of New Zealand (PIANZ) represents the interests of commercial poultry processors and livestock breeding companies in New Zealand. Its membership is responsible for over 99% of the country's poultry meat production.

The Egg Producers Federation of New Zealand (EPFNZ) is the national body that represents the interests of all commercial egg producers in this country, including free range, barn and caged egg farmers. EPFNZ is funded via producer levies under the Commodity Levies Act.

New Zealand currently has around 130 commercial egg producers, with the largest 20 producers accounting for over 75% of total production. In the 2009 to 2010 financial year, New Zealand had an estimated national flock size of 3,350,290 million laying hens (Statistics New Zealand 2011). However it is important to note that this national flock size will include commercial producers (i.e. EPFNZ members), small semi-commercial producers as well as backyard flocks.

In order to begin to improve the assumptions for poultry emissions estimates, further information on industry practices along with a national and international review on poultry emission estimates were required so that defaults currently used can be replaced by country specific information.

The next section will focus on both the national and international literature review on emissions from poultry. The proceeding section will cover the survey performed on the New Zealand meat chicken, layer, turkey and duck industries. The latter sections will cover the emissions factors and their uncertainties, conclusions and recommendations, populations statistics and finally the last section will focus on emission estimations from the above mentioned industry sectors.

3 LITERATURE REVIEW

3.1 Introduction

Globally, the poultry industry is one of the fastest growing agro-based industry due to increasing demands for egg and meat products (Bolan et al. 2010). However, little is known about the New Zealand (NZ) poultry industry's Greenhouse Gas emissions profile (Saggar 2008). In the NZ National Inventory Report (NIR) the poultry industry is currently classified as a minor livestock category (MfE 2010). As a result, IPCC Tier 1 methodology has been applied to calculate the poultry emissions (MfE 2010). The calculations use IPCC default emission factors (EFs) for 'Developed Countries' (IPCC 1996) as well as values derived from studies on other NZ agricultural industries such as dairy, sheep and beef (Carran et al. 1995; Muller et al. 1995; de Klein et al., 2003; Saggar et al. 2003; Thomas et al. 2005; Kelliher & de Klein 2006; Sherlock et al. 2009). However, no studies have been conducted to determine if these values accurately reflect NZ poultry industry practices.

3.2 Scope of the review

For the purpose of this review the NZ Poultry Industry encompasses meat chickens, layer hens, ducks and turkeys. However, in NZ 99% of the poultry population consists of meat chicken and laying hens; the remaining 1% is ducks and turkeys. Flock sizes of ducks and turkeys are currently unclear as they are reported by Statistics New Zealand (Stats New Zealand 2010) under 'Other Poultry' (PIANZ & EPFNZ 2010).

This document includes a review of: a) methane (CH_4) emissions from enteric fermentation and manure management; b) nitrous oxide (N_2O) emissions from manure management and manure application to agricultural soils; and c) indirect GHG emissions from agricultural soils in the NZ poultry industry, as calculated in the NIR. This review examines the current default EFs used in the NIR derived from the 'Revised 1996 IPCC Guidelines for National Inventories' (IPCC 1996) and the proposed '2006 IPCC Guidelines for National Greenhouse Gas Inventories' (IPCC 2006) as well as available national and international literature.

3.3 Methane emissions from enteric fermentation in New Zealand poultry industry

Ruminant animals such as cattle and sheep produce large quantities of CH_4 during their digestion process, where plant material is fermented by microbes (methanogens) in the rumen (IPCC 2001; MfE 2009; USEPA 2009). These microbes break down organic matter to produce volatile fatty acids (VFAs), carbon dioxide (CO_2) and CH_4. In 2008, NZ NIR enteric fermentation was calculated to contribute 22,657.5 Gg CO_2-e making it the largest key category for emissions in NZ (MfE 2010). This represents 30.3% of the total National CO_2-e emissions and 65.1% of agricultural emissions (MfE, 2010).

In NZ there has been extensive research on enteric fermentation EFs from ruminants (i.e. cattle: Lassey et al. 1997; Ulyatt et al. 2002a, b; and sheep: Judd et al. 1999; Ulyatt et al. 2002a, b, 2005). However, no literature was found reporting emissions from poultry.

Monogastric animals (such as poultry and pigs) do not have a rumen. But they do produce small amounts of CH_4 during digestion (Clark et al. 2001). The IPCC (1996) Tier 2 methodology allows for an enteric fermentation EF to be calculated through analysis of an animal feed, provided a methane conversion factor (Y_m) of the feed is established (see Equation 1).

$$EF = \left[\frac{GE \times (Y_m / 100) \times 365}{55.65}\right] \quad \text{(Equation 1)}$$

where**:** EF = emissions factor (kg CH_4 head^{-1} yr^{-1}); GE = gross energy intake (MJ head^{-1} day^{-1}); Y_m= the methane conversion rate expressed in a decimal form. The factor 55.65 (MJ/kg CH_4) is the energy content of methane

3.3.1 Feed quality

The composition of poultry feed varies considerably (European Commission 2003) in accordance with availability and affordability of feed. There is little published data on the current energy intake of NZ poultry available (Dr R. Ravindran,Massey University, pers. com.) as feed compositions used by companies are often closely guarded. In addition, feed gross energy (GE) rates are not specified in both IPCC guidelines (IPCC 1996, 2006). Estimated NZ average for GE and percent digestible energy (%DE) specified in a recent report by PIANZ and EPFNZ (2010) is given in Table 3.1.

Table 3.1 Diet (GE and DE) provided to NZ meat chicken and layer hens (Source: PIANZ 2009; EPFNZ 2010)

	GE (Mj/day)	% DE	Reference
Meat chicken	1.7±0.2	76.7±2.9%	PIANZ (2009)
Layer hen	1.3±	82.0±	EPFNZ (2010)

Diets given to poultry are complex and are changed to meet the growth and production requirements of the birds. For example, meat chickens produced by Ingham (2011) are given 4 specialist diets over their life cycle (Table 3.2). Furthermore, the amount of feed given to an animal can also be affected by the amount of work done by the bird. For poultry this is largely affected by the freedom of movement. Thus, caged housing reduces the amount of feed given to the birds. It is estimated that NZ caged layers receive 110 g feed day^{-1} feed while barn birds receive 120 g feed day^{-1} and free range 125 g feed day^{-1} (James Fick, PIANZ, pers. com.).

Table 3.2 Ingham Chicken Aviform categories of poultry diet (Source: Ingham 2011)

Meat chicken	Layer	Ducks	Turkey
Meat chicken starter 0–2 weeks	Layer chick starter 0–5 weeks	Duck starter 0–2 weeks	Turkey Pre Starter 0–3 weeks
Meat chicken Grower 2–4 weeks	Layer chick grower 6–17 weeks	Duck Grower 2 weeks – processing	Turkey starter 4–7 weeks
Meat chicken finisher 4–5 weeks	Commercial Layer 18 weeks – end of life		Turkey Grower 8–10 weeks
Meat chicken Withdrawal 5-processing			Turkey Fattener 11–13 weeks
Meat Chick starter 0–5 weeks			Turkey finisher 14 weeks – process
Meat Pullet developer 5–22 weeks			
Breeder 1 22–36 weeks			
Breeder 2 36 weeks – end of lay			

3.3.2 Methane conversion factor (Ym)

Although little is known about enteric fermentation processes in birds, they produce small amounts of CH_4 during digestion (McNab 1973; Marounek et al. 1999), which varies with the composition of bird diet (Tsukaharaand & Ushida 2000). Van Amsetel et al. (1993) concluded that enteric emissions from poultry are negligible. However, Corré & Oenema (1989) estimated CH_4 production in monogastric animals is less than 1% of the digestible feed intake and Crutzen et al. (1986) suggested around 0.6% of the GE intake is emitted as CH_4. Using a respiration chamber Wang and Huang (2005) quantified 15.78, 84.8 and 1500 mg bird^{-1}lifecycle^{-1} of CH_4 emission for commercial meat chickens, Taiwan country chickens, and White Roman Geese, respectively.

The limited literature on enteric CH_4 emissions from poultry resulted in the exclusion of enteric emissions from this industry in inventory calculations both in the IPCC Guidelines and both the guidelines regard enteric emissions from the poultry as 'Not Estimated' or 'Not Developed' (IPCC 1996, 2006). This does not imply that no emissions are produced by poultry but accepts that not enough data are available to make a clear assessment of enteric fermentation EFs from the poultry industry (Carlsson-Kanyama & González 2009). Tsukahara and Ushida (2000) note that while emission rates from individual poultry birds may be low when compared with ruminants, vast numbers of farmed poultry birds have the potential to significantly contribute to GHG emissions profile of a country. More accurate and precise measurements are needed to determine enteric emissions adequately from poultry, both nationally and internationally, before the emission calculations are included in the NIR.

3.4 Emissions from manure management in poultry

Poultry manure has the potential to produce significant quantities of CH_4 and N_2O, depending on the waste management practices. When manure is stored or treated under anaerobic conditions, such as lagoons and tanks, the decomposition of the biodegradable fraction of the waste tends to produce CH_4. When manure is handled as a solid, such as in stacks or deposits on pastures, the biodegradable fraction tends to decompose aerobically, greatly reducing CH_4 emissions (Saggar et al. 2004b, c). However, this practice may increase emissions of N_2O, which has a greater global warming potential than CH_4.

Manure management calculations for NIR refer to the CH_4 and N_2O emissions that are produced as a result of the storage and treatment of animal wastes (IPCC 2006). No indirect emissions are currently measured in the NIR.

In the following sub-sections the mechanisms of CH_4 and N_2O emission from manure management, effect of composition of poultry manure, methods of manure management in NZ and IPCC EFs in use for calculating emissions are discussed and reviewed.

3.4.1 Mechanisms of methane production from manure management

In poultry production, CH_4 is produced from the storage of manure (Monteny et al. 2001). Livestock manure comprises mostly urinary excretions as well as the fraction of the diet undigested by the birds, which consists largely of volatile solids (VS) and ash (indigestible compounds) (McGahan et al. 2009). The VS fraction of the manure has the potential to be broken down by microorganisms such as methanogens resulting in the production of CH_4 in a process called methanogenic fermentation (Equation 2).

$$C_6H_{12}0_6 \rightarrow 3CO_2 + 3CH_4 + \text{energy} \qquad \text{(Equation 2)}$$

The rate of manure decomposition and production of CH_4 depends on environmental conditions under which the manure is stored and treated, and the composition of the manure. Methanogenic fermentation occurs when poultry manure is stored under anaerobic conditions ($Eh<-200mV$) with low sulphate and nitrate concentrations (Saggar et al. 2004a). In theory this process is controlled by temperature, retention time, manure composition and the presence of inhibitory compounds such as ammonia (Zeeman 1991; Monteny et al. 2001). The method of storage and treatment (e.g., liquid, wet) has the potential to impact on these environmental parameters and, subsequently, the rate of CH_4 production. A range of Animal Waste Management Systems (AWMS) are used in the poultry industry depending on the animal subclass (meat chicken or layers) and the animal housing systems being applied (free range, barn or caged).

Of the current 719.5 Gg CO_2-e calculated from CH_4 emissions from manure management in NZ, the poultry industry contributes only 48.56 Gg CO_2-e (6.7%) (MfE 2010). The emissions from AWMS are calculated using an IPCC Tier 1 method (Equation 3) which applies a single default ‘Developed Country’ Manure Management Emission Factor (MEF) of 0.117kg head^{-1} yr^{-1} to all forms of poultry in a temperate environment (IPCC 1996, MfE 2010).

CH_4 emissions = MEF×Pn (Equation 3)

where: CH_4 emissions = the CH_4 emissions from a population via manure management ($kg yr^{-1}$); MEF is the EF for manure management; and Pn = the New Zealand poultry population

There is, however, considerable uncertainty in making this calculation (IPCC 1996). First, it is unclear why an EF for the temperate environment is used for NZ when the IPCC guidelines define 'temperate climate' with an average temperature of 15–25°C inclusive, and a 'cool climate' with an average temperature below 15°C. New Zealand temperature reports suggest average temperature for the 2009 calendar year was 12.3°C, with a 10-year average temperature of 12.6°C (NIWA 2010). Thus New Zealand should be classified under 'cool climate' for determining emissions for the Manure Management sector. Consequently, a MEF of 0.078 kg $head^{-1}$ yr^{-1} could be applied if IPCC default values (IPCC 1996) are used in future NIR.

Second, the proposed IPCC (2006) Guidelines are yet to be introduced into the NIR globally, and recommend new default emission values for poultry that in general are lower than the IPCC (1996) default values. The proposed IPCC (2006) guidelines break down poultry into animal subclasses (meat chicken, layer, ducks and turkeys), and outline basic manure management techniques (e.g., wet and dry layers) commonly used in the poultry industry (Table 3.3). The revised MEF indicates that the current MEF value of 0.117kg $head^{-1}$ yr^{-1} overestimates CH_4 emissions from NZ poultry because this value is now thought to represent layer chickens using wet AWMS. Layer chickens using dry AWMS and meat chickens produce significantly lower emissions of 0.03 and 0.02 kg $head^{-1}yr^{-1}$, respectively, while the layer hens using wet AWMS produce significantly higher emissions of 1.4 kg $head^{-1}yr^{-1}$ (Table 3.3).

Table 3.3MEF factors by bird subclass in the Proposed IPCC 2006 Guidelines for National Inventories (Source: IPCC 2006)

Poultry	CH_4 EF (kg CH_4 $head^{-1}$ yr^{-1})	
	Cool (<15°C)	Temperate (15–25°C)
Layers (dry)	0.03	0.03
Layers (Wet)	1.2	1.4
Meat chickens	0.02	0.02
Turkeys	0.09	0.09
Ducks	0.02	0.03

Uncertainty in emission factors ±30%

The large differences between the IPCC (1996) and IPCC (2006) default values result from a review of the assumptions used to calculate EF. MEF default values are calculated using the Tier 2 methodology (Equation 4) for manure management. The methodology requires specific assumptions on manure characteristics to be included in the equation such as VS content and B_o for the poultry manure.

$$EF = [VS_{(t)} \times 365 \, (B_o \times 0.67 kg/m^3 \times \sum MCF \times MS \, \%]$$ (Equation 4)

where: EF = Emissions factor (manure management) kg CH_4 animal^{-1}yr^{-1}; $VS_{(t)}$ = Daily volatile solids excreted from a kg dry matter animal^{-1}yr^{-1}; 365 = conversion from days to year; B_0 = maximum methane producing capacity for manure produced from excreta (m^3CH_4 kg^{-1} of VS excreted); 0.67 = conversion factor of m^3 CH_4 to kg CH_4; MCF = methane conversion factor for each manure management system, (decimal); and MS = Fraction of livestock manure using AWMS (decimal).

In the following sections of this report we discuss the key variables such as VS contained within poultry manure, CH_4 producing potential (Bo), CH_4 conversion factors (MCF) based on the environmental conditions of AWMS used on the farm, and fraction of livestock manure entering each AWMS involved in CH_4 emissions from manure management in the NZ poultry industry..

3.4.2 Mechanisms of nitrous oxide production from manure management

Nitrous oxide is mainly produced during aerobic storage and treatment of animal excreta as well as after land-spreading (Saggar et al. 2004a). However, for the manure management section, only emissions from the storage and treatment of manure are considered. Emissions from the land application of poultry manure to soils are calculated and included in the agricultural soils section.

Nitrous oxide emissions result from incomplete nitrification and denitrification reactions in AWMS. Nitrous oxide production by nitrifying bacteria may arise either during NH_4^+ oxidation to NO_2^- or during dissimilatory NO_2^- reduction when O_2 supply is limited (Saggar et al. 2009). The rate of nitrification is influenced by environmental factors such as available oxygen, temperature, pH and the concentration of other nutrients in the manure mix, such as phosphate which has the potential to limit nitrification rates (Laurenson et al. 2006). Denitrification is stimulated by the presence of denitrifying bacteria, a temperature greater than 4°C, an anoxic environment and a source of carbon (Laurenson et al. 2006), where bacteria convert NO_3^- to N_2. However, this process is often incomplete under field conditions with NO and N_2O released as by-products.

Nitrous oxide emissions from AWMS calculated in the NIR reflect a relationship between the amount of nitrogen (N) being excreted (Nex) from an animal and the environmental conditions in which the manure is treated (aerobic or anaerobic) (EF_3) (Equation 5).

$$N_2O_{D(mm)} = [\sum(N \times Nex \times MS)] \times EF_3 \times 44/28$$ (Equation 5)

where: $N_2O_{D(mm)}$=direct N_2O emissions from manure management; N = Population; N_{ex} = Annual average N excretion per head; MS = fraction of total annual other livestock excretion in each manure management system; EF_3 = EF for manure in management system (1996 IPCC values)

Data strongly suggest the type of AWMS used to treat manure has a major impact on N_2O emissions (Redding 2009). When optimum conditions for denitrification are met, NO_3^- in a given AWMS will be reduced to N_2 gas resulting in a low EF_3. However, nitrification or denitrification reactions in some AWMS can result in significant N_2O emissions. The IPCC applies the following key variables to calculate N_2O emissions from manure management.

1. Nitrogen excretion rates per animal (Nex)

2. Fraction of livestock manure entering each animal waste management system (MS);

3. Nitrous oxide emission factors for manure management (EF_3).

These variables are discussed in sections 3.4.3.2, 3.5.1 and 3.5.3 of this report.

3.4.3 Composition of poultry manure

The calculation of both CH_4 and N_2O emissions is based on assumptions made about the chemical and physical composition of NZ poultry manure. Poultry manure can consist of a combination of bedding material, feathers, broken eggs, manure and spilt feed (Kelleher 2002). The composition of manure will vary depending on the type of poultry, animal housing, litter type, feed composition and feeding method, retention time of the manure, and the handling and storage operations in place within a given AWMS (Smith et al. 2000; Bolan et al. 2010). The amount of feed spilt within the animal housing can also significantly affect the total amount of solids and nutrients within the litter/manure.

The current IPCC methodology applies default values for key manure parameters (such as VS, Nex, and MPP; (Equation 4 and 5) to determine emissions. Due to limited availability of NZ Data on these key parameters IPCC (1996) default EFs are used in NZ NIR (MfE, 2010).The key parameters used in EFs are discussed below:

3.4.3.1 Volatile solids (VS) concentrations in manure

The quantity of VS and ash within excreta can vary according to the digestibility of the bird diet as well as the nutritional requirements of each poultry species (layer, ducks and turkeys). IPCC (1996) guidelines recommend VS concentrations for most animal species (ruminants and non-ruminants) be determined using Equation 6 (IPCC 1996). However, the proposed IPCC (2006) guidelines recommend the use of measured VS excretion from poultry rather than applying this equation.

$$VS(kgdm.day^{-1}) = GE \times \frac{1}{18.45} \times \left(1 - \frac{DE\%}{100}\right) \times \left(1 - \frac{ASH\%}{100}\right) \qquad \text{(Equation 6)}$$

where: VS = volatile solid excretion per day on a dry-organic matter basis, (kg VS day^{-1}); GE = gross energy intake from feed (MJ day^{-1}); 18.45 = conversion factor for dietary GE per kg of dry matter (MJ kg^{-1}); DE = digestibility of the feed in per cent; and ASH = the ash content of the manure in per cent.

Because the NZ NIR applies the IPCC (1996) default emission factor for methane, the development of this figure is from the VS value for 'Developed Countries' of 0.1 kg day^{-1} for all forms of poultry (i.e. chickens, ducks and turkeys)(MfE 2010 and IPCC 1996). However, in NZ data on VS excretion rates from poultry are very limited. The PIANZ & EPFNZ (2010) reviewed the IPCC default VS values using Equation 6 and recommended VS excretion value of 0.015 kg VS day^{-1} for meat chickens and 0.009 kg VS day^{-1} for layer hens.

The values calculated by PIANZ suggest the IPCC (1996) default value overestimates VS excretion rates (PIANZ & EPFNZ 2010). This has been confirmed in an earlier review of the NZ literature (NZAEI 1984). The New Zealand Agricultural Engineering Institute (NZAEI 1984) reported an emission rate of 0.019kg VS day^{-1} for layer chicken manure. Their data indicated that the IPCC default value of 0.1kg VS day^{-1} is valid only with larger birds such as turkeys with a VS excretion rate 0.11 kg excreta day^{-1}. An earlier MAF report (MAF 1985) indicated that the IPCC default value is similar to the total manure excreted from a layer or meat chicken but not the VS excretion (Table 3.4)

Table 3.4 Approximate quantities of manure produced per bird per day (MAF 1985)

Animal	Fresh Manure (kg/d)	Total solids (% fresh)	Total solids (kg/d)
Turkey	0.4	25	0.09
Layer hen	0.12	25	0.03
Meat chicken	0.10	21	0.02

The proposed IPCC guidelines have revised the VS excretion rates for poultry manure to 0.01 and 0.02 kg VS day^{-1} for meat chickens and layers, respectively, and 0.07 and 0.02 VS day^{-1} for turkeys and ducks, respectively (IPCC 2006). This review of the literature indicates these updated values are more appropriate with poultry VS excretion rates, both nationally and internationally.

3.4.3.2 N excretion per head (Nex)

The N excretion per head (Nex) forms the basis for all N_2O emission calculations in the inventory (IPCC 1996). Poultry manure contains four forms of N: complex organic N (in feathers shed and undigested feed and bedding material); labile organic N (in uric acid and urea); ammonia N; and nitrate N (Bolan et al. 2010). Nitrogen in these forms is constantly transformed by microbial activity as well as by changes in temperature, pH, moisture and oxygen concentrations (Kelleher et al. 2002). The uric acid in poultry manure rapidly hydrolyses to ammonium by the urease enzyme. Nitrate ions can be formed by the oxidation of ammonium ions during aerobic composting (Bolan et al. 2010). Published figures on N composition for poultry manure vary widely (Smith et al. 2000) as N composition depends upon bird type (meat chicken, layers, turkey, etc.), bird diet, litter type, handling, and storage operations (Nicholson et al. 1996). Smith et al. (2000) noted that changes in production systems in recent years might also have had an effect on Nex recorded over time.

Large quantities of N are consumed and excreted by poultry due to an excess of amino acids and protein contained within the bird feed (Blair et al. 1999; Kelleher et al. 2002; Rotz et al. 2004) (Table 3.5). Essential amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine (+cystine), phenylalanine (+tyrosine), threonine, tryptophan and valine) for poultry are sourced externally, as their metabolism cannot supply them (European Commission 2003). Individual poultry diet varies with their production requirements (Latshaw & Zhao 2011) and amino acid requirements vary with age, sex, genotype and production function (Han & Lee 2000). Rotz et al. (2004) estimated that less than 30–50% of N in amino acids in feed is incorporated into protein in the birds, and the remaining N is excreted.

Table 3.5 Crude Protein content in feeds (source: European Commission 2003)

Animal	Phase	Crude Protein Content (% in feed)
Meat chicken	Starter	20–22
	Grower	19–21
	Finisher	18–20
Turkey	<4 weeks	24–27
	5–8 weeks	22–24
	9–12 weeks	19–21
	13+ weeks	16–19
Layer	18–40 weeks	15–16.5
	40+ weeks	14.5 – 15.5

Studies to formulate diets that reduce the crude protein content while providing birds with requisite essential amino acids (Blair et al. 1999; Latshaw & Zhao 2011) show that reducing the crude protein content can reduce N excretion in meat chickens by10–27% during the 6-week rearing period and by 30–35% in layers, without compromising production. Manure management techniques and the retention time of solids in AWMS also has an effect on manure N concentrations. Bolan et al. (2010) reported the quantity of N in the litter of layers and meat chickens was 32.8 and 25.7 g/kg (DW basis), respectively. The range in total N (TN) concentrations found through analysis of poultry manure (Table 3.6) is consistent with the wide range in management practices for manure used in the poultry industry.

Table 3.6 Range in TN % dry weight (DW) and fresh weight (FW) kg/T (Source: Mahimairaja et al. 1994; Nicholson et al. 1996; Smith et al. 1999; Webb & Hawkes 1985; Western Australian Broiler Growers Association & Poultry Farmers Association of Western Australia 2004)

	TN% (DW)	TN (kgT^{-1}) FW
Layer	1.3 – 14.7	11.0–57
Meat chicken	1.3 – 10.1	19–46
Turkey	3.5 – 70.2	16–45
Duck	1.9 – 6.6	4.0 – 25

Currently the IPCC and NIR use a single value for all poultry of 0.6 kg N yr^{-1}.

A summary of VS and Nex rates reported in New Zealand and from the international literature is given in Table 3.7.

Table 3.7 New Zealand and international VS and Nex excretion rates from poultry

Reference		kg bird^{-1} VS day^{-1}	Nex (kg yr^{-1})	Nex (kg N 1000 kg animal mass^{-1}yr^{-1})
1996 IPCC and NIR value	All poultry	0.10	0.6	
	NZ Literature			
NZAEI (1985)	Layers	0.019	0.511	
PIANZ and EPFNZ (2010)	Layers	0.009	0.32	
MAF (1986); Mahimairaja et al. (1993)	Meat chickens	0.0233 *	NA	
PIANZ and EPFNZ(2010)	Meat chickens	0.015	0.39	
NZAEI (1985)	Turkeys	0.11	3.0	
	International Literature			
Brown (2001)	All Poultry		1.78	
Bouwman et al. (1997)	All Poultry		0.5	
Smil (1999)	All Poultry		0.3	
Mosier et al. (1998)	All Poultry		0.6	
IPCC (2006)	Meat chickens	0.01		1.10
ASAE (2005)	Meat chickens	0.0198	0.403	
Smith et al. (1999)	Meat chickens (places)		0.495	
Smith et al. (1999)	Meat chicken breeders		0.975	
IPCC (2006)	Layer	0.02		0.82
ASAE (2005)	Layer	0.016	0.584	
Smith et al. (1999)	Layer		0.66	
Smith et al. (1999)	Pullets		0.125	
Manitoba Agriculture (1995); Smith et al. (1999)	Pullets		0.240	
Walther et al. (1994); Smith et al. (1999)	Pullets		0.340	
Laursen (1995); Smith et al. (1999)	Pullets		0.123	
PARCOM (1996); Smith et al. (1999)	Pullets		0.280	
IPCC (2006)	Pullets			0.6
IPCC (2006)	Turkey	0.07		0.74
ASAE (2005)	Turkey (male)	0.0556	1.5	
Smith et al. (1999)	Turkey (male)		1.39	
ASAE (2005)	Turkey (female)	0.0333	0.904	
Smith et al. (1999)	Turkey (female)		0.650	
ASAE (2005)	Ducks	0.0256	0.580	
IPCC (2006)	Ducks	0.02		0.83
Smith et al. (1999)	Ducks		0.900	

3.4.3.3 *Methane production potential (B_o)*

Poultry manure has a higher fraction of biodegradable organic matter than any other livestock waste (Bujoczek 2000; Kelleher et al. 2002) and can degrade rapidly within AWMS. However, in digesters the rate of CH_4 production can be affected by inhibiting compounds such as ammonia. Methane Production Potential (referred to as B_o) is the maximum amount of CH_4 that can be produced from a given quantity of manure in a controlled laboratory environment (m^3 CH_4/Kg VS added). Only a limited number of reported B_o values were found for poultry manure.

Table 3.8 Methane production potential (Bo) values

Animal type	Bo m^3/kg/VS added	Reference
All Poultry	0.32 developed 0.24 developing	IPCC (1996); Woodbury & Hashimoto (1993)
Layer	0.39 ± 15%	IPCC (2006); Woodbury & Hashimoto (1993)
Layer	0.346	Yang & Change (1978)
Layers	0.496	Webb & Hawkes (1985)
Meat chickens	0.36 ± 15%	IPCC (2006); Woodbury & Hashimoto (1993)
Meat chickens	0.39	Field et al. (1985)
Turkey	0.36 ± 15%	IPCC (2006); Woodbury & Hashimoto (1993)
Ducks	0.36 ± 15%	IPCC (2006); Woodbury & Hashimoto (1993)

It is concluded from the NZ and international literature reviewed above that the current default VS value (0.01 kg VS day^{-1}) applied to NZ poultry calculations is overestimated. We also found that use of IPCC (1996) default values for calculating CH_4 in the Manure Management section of the NZ NIR results in higher CH_4 emissions recorded from the poultry industry. The review of NZ literature suggested that the current Nex default value of 0.6 kg $animal^{-1}$ $year^{-1}$ may overestimate N excretion rates for NZ layer and meat chickens. However, there is a wide range of N excretion values reported in the international literature. Given that layers and meat chickens in NZ represent approximately 99% of the poultry animal population, further sampling work is required to determine how representative the current default value is for the NZ poultry industry. This review also showed that, for calculating both CH_4 and N_2O emissions from poultry industry, the division of the population into subclasses (i.e. meat chicken, layer, duck and turkey) and the use of the proposed IPCC (2006) default values would improve accuracy of the VS and Nex parameters.

3.5 Animal waste management systems (AWMS) in NZ

Emission calculations within the NIR include assumptions made on the quantity of manure being treated by each AWMS, as well as the CH_4 and N_2O emitted from each system based on VS and Nex loading rates. The following section reviews the default values applied to the fraction of total annual livestock effluent treated/stored in each manure management system (MS), as well as the methane conversion factors (MCF) and N_2O emission factors for manure in management systems (EF_3), to determine if these factors are representative of NZ industry practices.

3.5.1 Fraction of annual livestock excretion in each manure management system (MS)

Both CH_4 and N_2O emission calculations in the NIR require data on the fraction of annual livestock excretion treated within each AWMS. To ensure consistency throughout national inventories globally, the IPCC (1996; 2006) guidelines provide definitions of AWMS used on farms to determine the proportion of animal waste treated in each system (Table 3.9).

The current IPCC (1996) definitions do not apply to specific poultry farm operations. Consequently, NIR assumes that 97% of poultry manure is treated through a generic ‘other’ treatment category, and the remaining 3% is assigned as ‘going direct to pasture range and paddock through free range animals’. Both categories assume that no poultry waste is treated by wet treatment systems.

The proposed IPCC (2006) definitions, however, provide a more industry-specific breakdown of categories assigned for poultry manure treated with and without litter. There is uncertainty surrounding these proposed IPCC (2006) values as no data are available that provide an accurate breakdown of the methods of AWMS for use in NZ, or the proportion of waste that each AWMS treats in the NZ poultry industry. Consequently, it is unknown if the default MS values accurately represent NZ poultry manure management practices.

Table 3.9IPCC AWMS definitions in IPCC 1996 and 2006 Guidelines

AWMS	Definition
	(IPCC 1996 definitions)

Anaerobic lagoon	Anaerobic lagoon systems are characterised by flush systems that use water to transport manure to lagoons. The manure resides in the lagoon for periods from 30 days to over 200 days. The water from the lagoon may be recycled as flush water or used to irrigate and fertilise fields.
Pasture range paddock	The manure from pasture and free-range grazing animals is allowed to lie as is, and is not managed.
Solid Storage	Manure is collected as in the daily spread system, but is stored in bulk for a long period of time (months) before any disposal.
Other	No definition provided
(IPCC 2006 definitions)	
Poultry manure with litter	Similar to deep bedding systems. Typically used for all poultry breeder flocks and for the production of meat type chickens (meat chickens) and other fowl.
Poultry manure without litter	May be similar to open pits in enclosed animal confinement facilities or may be designed and operated to dry the manure as it accumulates. The latter is known as a high-rise manure management system and is a form of passive windrow composting when designed and operated properly.
Composting	Composting – in vessel. Composting, typically in an enclosed channel, with forced aeration and continuous mixing. Composting – Static pile. Composting in piles with forced aeration but no mixing. Composting – Intensive windrow. Composting in windrows with regular (at least daily) turning for mixing and aeration. Composting – Passive windrow. Composting in windrows with infrequent turning for mixing and aeration.

The AWMS of layer hens vary depending on the animal housing operation employed. The NZ egg production industry has three types of housing methods: 87% in caged egg production; 10% in free range systems; and the remaining 3% in the barn layer system (EPFNZ 2010). Free range chickens are defined by the Animal Welfare Code of Practice to be 'a system providing birds with access to an extensive outdoor area and which typically includes housing (either fixed or moveable) similar to a barn, aviary or perchery without cages'. In a barn system, birds are kept in a large shed with a litter floor. The practice in NZ for cage and enriched cage birds is that conveyor belts capture the manure underneath the cages. This is then dried in the shed (this is probably due to the ventilation systems utilised in the sheds), the belts are turned on, and the manure is collected (usually in 'bags') at one end of the shed. The bags are usually emptied weekly, during which the dried manure bags are taken and trucked over to the intended destination by a manure removal contracting company (James Fick, pers. com.). The liquid manure management systems are outdated and are no longer used by the vast majority of the layer industry (probably since the year 2000 or so). Some liquid management systems have been observed, including in the largest egg producing farm in New Zealand operated by Mainland Poultry at Waikouaiti near Dunedin in the South Island (MWH 2008). One farmer in the NZ survey collects the manure, stores it, combines it with a neighbour's dairy effluent storage until use, and then spreads it directly onto pasture (Jame Fick, pers. com.).

The NZ commercial flock of meat chickens are produced predominantly (97%) in sheds with floor litter and 3% is produced free-range (PIANZ and EPFNZ 2010). Turkeys are housed predominantly in barns (83%); the remainder are free-range. Ducks are largely barn reared. Barn layers, free-range poultry, meat chickens and turkeys generally have litter systems at the base of the enclosures that are removed periodically (in some cases only once a year). However, it is estimated that in NZ meat chickens there are approximately 6.2 cycles or clean outs per year (James Fick, pers. com.). Between rotations, the caked layer of manure can be removed with fresh litter placed on the surface. The removed litter is in a composted form, but in most cases a stand-down period of 21 days is required before land application (James Fick, pers. com.)Due to limited data available on NZ AWMS there may be some variation to the reported IPCC MCF. Further information on AWMS is collected by the industry to determine the accuracy of the values applied.

3.5.2 Methane conversion factors (MCF)

The methane conversion factor (MCF) relates the proportion of Bo converted to CH_4 during the storage and treatment of the animal waste. The IPCC (2006) note that MCF values vary according to the manner in which the manure is managed (retention time), and the climate (temperature). MCF values can theoretically range from 0 to 100% of the B_o. However, in practice the quantity of CH_4 produced by an AWMS will always be lower than the B_o because environmental conditions (pH, temperature, availability of substrate, oxygen) are not optimal for CH_4 production (Hüther et al. 1997). Additionally, the presence of inhibitors such as ammonia and volatile fatty acids can inhibit methanogenesis (Møller et al. 2004).

Manure managed as a liquid under warm conditions for an extended period of time promotes CH_4 formation and as a result these conditions are associated with high MCFs (65–80% of B_o). In contrast, manure managed as dry material in cold climates does not readily produce CH_4, and consequently has an MCF of about 1%. Saggar (2008) noted that poultry manure is normally removed from the production environment quickly in a dry state, reducing the likelihood of high CH_4 emissions.

Because MfE uses the defalut emission factor, the MCF 9i.e. 1.5%) is therefore included in the figure for all poultry-related emissions from manure management, assuming all emissions are under dry AWMS conditions (MfE 2010). These values for the NIR are generally recommended based on IPCC working group recommendations rather than measured emissions from field or laboratory studies. Globally there have been a limited number of studies that link VS loading rates with CH_4 emissions, particularly in dry AWMS.

3.5.3 Nitrous oxide emission factor (EF_3)for manure in the management system

The percentage of Nex that is converted to N_2O emissions from a given AWMS is represented by the EF_3 in the NIR. Environmental conditions in AWMS affect N_2O emissions. Currently, the NZ NIR uses IPCC default values to calculate N_2O emissions from poultry AWMS. The IPCC 1996 guidelines report an EF_3 value of 0.02 kg N_2O-N kg^{-1} Nex for solid storage and drylot, with a reported range of 0.005-0.03 kg N_2O-N kg^{-1} Nex. For 'Other' systems the guidelines recommend an EF_3 of 0.005 kg N_2O-N kg^{-1} Nex. The 2006 IPCC guidelines do not have an 'Other' systems category but provide EF_3 values for poultry-specific AWMS (e.g., poultry manure with and without litter are reported to have an EF_3 of

0.001 kg N_2O-N kg^{-1} Nex based on the judgment of an IPCC Expert Group). The group argues that poultry manure has a high loss of ammonia from these systems, which limits the availability of N for nitrification/denitrification. The use of this proposed poultry specific EF_3 will result in lower N_2O emissions than are reported from the industry.

During this review it was observed that the current breakdown of the proportion of poultry using each manure management system (MS) and assigning manure to the Pasture/Range and Paddock category as well as the 'Other' category, limits the accuracy of poultry-specific MCF and EF_3 values that can be applied. Therefore, in the following sections we review MCF and EF_3 data for poultry specific AWMS. These values could be applied to the NZ poultry industry NIR for estimating a detailed country-specific AWMS emission.

3.6 Emissions during dry Storage (litter and non-litter systems)

Litter systems where faecal matter is kept predominantly dry contribute less CH_4 emissions than wet anaerobic systems (IPCC 2006). Due to limited international data available on CH_4 and N_2O emissions from dry lot poultry manure storage the proposed IPCC (2006) guidelines recommend the use of a MCF value of 1.5% of $B_{o,}$ as determined by an expert panel.

N_2O emissions from dry litter systems are higher than liquid-based systems. Rotz (2004) noted that there is a complex microbial decomposition process occurring within litter including aerobic and anaerobic degradation of organic matter, urea or uric acids hydrolysis, nitrification, denitrification and N immobilization. Deep bedding contains both aerobic and anaerobic microsites where soluble carbon, moisture and heat result in favorable conditions for N_2O production (Thorman et al. 2007). However, N_2O emissions from poultry manure are lower than those from other deep litter systems due to the high loss of ammonia from these systems. This limits the availability of N for nitrification/denitrification (IPCC 2006). As a result, a separate EF_3 factor of 0.001 kg N_2O-N kg^{-1} Nex has been determined, based on the judgment of an IPCC Expert Group.

A limited number of studies examined CH_4 and N_2O emissions from poultry litter (Table 3.10). These studies focused on ambient CH_4 and N_2O emissions from layer poultry sheds, and reported emissions in kg $place^{-1}yr^{-1}$ rather than based on B_o conversion rates. Jungbluth *et al*. (2001) noted that CH_4 and N_2O emissions from poultry layer hens have to be assessed critically as they vary greatly between animals, and measured concentrations are often very low.

Table 3.10N_2O and CH_4 emission factors from littered poultry facilities

Housing system	N_2O kg $place^{-1}yr^{-1}$	CH_4 kg $place^{-1}yr^{-1}$	Reference
Layering hens – straw	0.017	0.076	Mennicken (1998); Jungbluth et al. (2001)
Layering hens – wood	0.043 – 0.079	0.254 – 0.383	Mennicken (1998); Jungbluth et al. (2001)
Layer hens – ¾ straw ¼ wood	0.155	0.34[1]	Mennicken (1998); Jungbluth et al. (2001)

Layer hen, free range	0.06	Groot et al. (1997); Monteny et al. (2001)
Meat chicken, Litter	0.02	Groot et al. (1997); Monteny et al. (2001)

Non-litter systems generally pertain to caged layer animals. There has been limited research on emissions from these systems. Fabbri et al. (2007) compared GHG emissions from two layer systems: a) deep pits that are forcibly aerated; and b) a manure removal system where droppings are removed on a conveyor belt. They found significantly higher CH_4 emissions from the conveyor belt system (0.081 kg place^{-1}yr^{-1}) compared with deep pit system (0.029 kg place^{-1}yr^{-1}), while N_2O emissions from both these systems were negligible (0). The emissions from non-littered poultry facilities are summasrised in Table 3.11.

The IPCC (2006) Guidelines recommend a default MCF for regions with temperate environmental conditions that manage poultry manure with or without litter of 1.5% IPCC (2006). The IPCC (2006) Guidelines also recommend adirect emission factor (from manure management systems),EF_3, of 0.001 N_2O-N kg^{-1} Nex for poultry manure with and without litter. Thus the division from the 'Other' category to the poultry specific categories being 'Poultry manure with Litter 'and 'Poultry Manure without litter' in the proposed IPCC (2006) guidelines, would result in a reduction in recorded emissions from this source. This separation would result in a reduction in EF_3 values used for both categories from 0.005 to 0.001 kg N_2O-N kg^{-1} Nex.

Table 3.11N_2O and CH_4 emission factors from non-littered poultry facilities

Housing system	N_2O	CH_4	Reference
Battery caged/aviary systems	0.95 gh^{-1}LU^{-1}	-	Sneath et al. (1996); Jungbluth et al. (2001)
Layering hens – wood	0.02 – 0.15 gh^{-1}LU^{-1}	Not detectable	Neser et al. (1997); Jungbluth et al. (2001)
Layer hens – ¾ straw ¼ wood	0.05 – 0.35 gh^{-1}LU^{-1}	Not detectable	Neser et al. (1997); Jungbluth et al. (2001)
Caged Deep pit-aerated	Not detectable	0.029 kg place^{-1}yr^{-1} 1.04 gh^{-1}LU^{-1}	Fabbri et al. (2007)
Caged – Ventilation belt	Not detectable	0.081 kg place^{-1}yr^{-1} 2.15 gh^{-1}LU^{-1}	Fabbri et al. (2007)
Layer hens caged		0.06 kg place^{-1}yr^{-1}	Groot et al. (1997); Monteny et al. (2001)

3.7 Emissions during composting

In NZ all poultry manure undergoes a stand-down of 14–21 days before land application. Only a small proportion (3–4%) of the manure produced undergoes more intensive composting (PIANZ and EPFNZ 2010). The manure is 'hot' composted in the thermophilic range (50–70^{o}C) for 3 days (Saggar 2008), followed by a maturing process of 2–3 weeks (Poultry Association 2003). Composting poultry manure increases the aerobic microbial decomposition and generates sufficient heat to raise the temperature of the compost to the thermophilic zone (Litterick 2003). The process causes pathogen die-back and results in an end material that is biologically stable and odour-free (Moore et al. 1995).

Methane emissions during composting are usually related to a lack of oxygen in the rotting biomass. The characteristics of the raw material, the height and shape of the pile, control of moisture content and turning frequency are the main factors which influence aeration of the pile and subsequent CH_4 production (Peigne & Girardin 2004). A range of composting techniques can be used, including natural or forced aeration of the manure pile. The chosen method will influence the oxygen content within the stockpile and resulting CH_4 emissions.

N_2O emissions from the composting process are influenced by temperature, N content (especially NO_3^-) and aeration (Peigne & Girardin 2004). During the composting process N_2O can be produced early during the maturation phase (He et al. 2000). However, temperature increases can inhibit nitrification, reducing emissions during later phases (Hellmann et al. 1997).

No data are available on CH_4 and N_2O emissions from composted poultry manure. Consequently, Table 3.12 provides emissions from other sources of compost. Hüther et al. (1997) found CH_4 and N_2O emissions from the stockpile relate directly to air movement through the pile. They reported that 2.5% of the total C and 1.5% of the total N was emitted as CH_4 and N_2O, respectively from the farm yard manure (FYM) when aeration of the pile was 1.8m^3 hr^{-1}.Emissions were drastically reduced with a higher aeration rate in composting FYM. They were also linked to the moisture content of the FYM, with emissions decreasing dramatically with solid contents greater than 18% (Hüther et al. 1997). Ballestero and Douglas (1996) reported 2.2% of total N was emitted as N_2O during composting of farm waste (bedding with horse manure and poultry manure).

Table 3.12 Estimates of nitrous oxide emissions from research studies (Paul et al. 2001)

Compost	Method	N_2O-N loss (% of total N)	Reference
Yard waste	Turned windrow	0.5	Hellebrand 1998
Food &yard waste (80:20)	Widrow & agitated	0.2 – 0.4	Schenk 1997
Wastewater sludge	Aerated static pile	0.7	Czepiel et al. 1996
Cattle & horse manure	Turned windrow	0.5	Czepiel et al. 1996
Yard waste	Turned windrow	1.2	Ballestero et al. 1996
Horse manure & bedding	Turned windrow (>60 days)	2.2	Ballestero et al. 1996
Swine manure & cardboard	Aerated & turned in vessel	0.1	Kuroda et al. 1996
Animal manure	Heaps in containers	5	Martin & Dews 1992
Cattle manure	Passively aerated windrows	0.11	Hao et al. 2001
Cattle manure	Turned windrow	0.19	Hao et al. 2001
Swine manure & straw	Passively aerated pile	0.8	Sommer & Moller 2000

Composting is a new category outlined in the IPCC (2006) methodology. The current IPCC guidelines used within the NIR are outlined in Table 3.13 with IPCC updated values for composting MCF and EF_3 .However, none of the references have specifically examined composting of poultry manure.

Table 3.13 IPCC 1996 and 2006 MCF and EF_3

	MCF	EF_3
	IPCC 1996	
Solid storage	1% cool 1.5% temperate 2% warm	Other 0.005
	IPCC 2006	
Composting – in vessel	0.5% Judgment of IPCC Expert Group and Amon *et al*. (1998). MCFs are less than half of solid storage. Not temperature dependant.	0.006 (Factor 2) Judgement of IPCC Expert Group. Expected to be similar to static piles
Composting – Static pile	0.5% Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are less than half of solid storage. Not temperature dependant	0.006 (Factor 2) Hao *et al*. (2001).
Composting – Intensive windrow	0.5% cool 1% temperate 1.5% warm Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are slightly less than solid storage. Less temperature dependant.	0.1 (Factor 2) Judgment of IPCC Expert Group. Expected to be greater than passive windrows and intensive composting operations, as emissions are a function of the turning frequency.
Composting – Passive windrow	0.5% cool 1% temperate 1.5% warm Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are slightly less than solid storage. Less temperature dependant	0.01 (Factor 2) Hao et al. (2001).

It is unclear how the composting value should be applied in inventory calculations, as the composting process is generally additional to the storage of manure already factored into previous MCF and EF_3 calculations (e.g., poultry manure with litter). Further clarification is required to determine if the emission values include emissions as a result of storage or if emissions from composting are additional to these values. On examining the default values, particularly the MCF values for windrows, it appears that these values should be included in the preliminary manure storage step, as a MCF for composting in passive windrows (1%) is less than that for manure treated in a dry state (1.5%, with or without litter). If this is so, composted material that is treated in windrows should have an MCF of 2.5% (which is the combined value of the windrow figure and the dry state factor). However, there are inherent problems with the simple addition of MCF as it might overestimate emissions. This is illustrated by an example of a combined AWMS with pit storage below an animal confinement flushed into an anaerobic lagoon, which have MCF values of 42% and 78% respectively at 20^{o}C (IPCC 2006). The addition of these two values would result in a MCF of 120%. This demonstrates that MCF values are not designed for combined AWMS.

It is unclear at what stage in a stand-down period the manure is regarded as composted material. Without clear definitions, all poultry manure undergoing the stand-down period could be interpreted as undergoing a passive windrow composting step, and as a result accumulate emissions. Further clarification is required from the IPCC as to how these values are intended to be applied to poultry manure in a stand-down period.

3.8 Emission in anaerobic lagoons

In anaerobic lagoons organic wastes are biologically degraded through anaerobic fermentation to CO_2, CH_4 and H_2S (Saggar et al. 2004a), which are released into the atmosphere in the form of biogas. The concentration of biogas released can vary depending upon the environmental conditions (e.g., temperature) and the management practices (e.g., VS loading rates, retention time) (Safley & Westerman 1988). Production of CH_4 has been reported to increase linearly with temperature over the optimum range 10-20°C (Sutter and Wellinger 1985). A NZ study using dairy and piggery waste through anaerobic lagoons (Craggs et al. 2008) reported CH_4 production varied over the course of a calendar year with highest emissions occurring in the summer months (Figure 1). The results demonstrate the importance of including temperature parameters into IPCC equations. For the NZ poultry industry, the use of anaerobic lagoons or ponds to treat manure from caged layer systems is outdated and is no longer used by the vast majority of the layer industry (probably since about the year 2000) (James Fick, pers. com.).

The IPCC (1996) guidelines give a single conversion rate of 90% of Bo regardless of temperature (cool, temperate, warm), based on studies by Safley et al. (1992) and Safley and Westerman (1992). However, the proposed IPCC (2006) guidelines allow temperature adjustments, based on the judgment of IPCC Expert Group and the findings of Mangino *et al*. (2001). These guidelines recommend MCF values of 66% for $\leq 10^{o}C$ to 80% for $\geq 28^{o}C$.

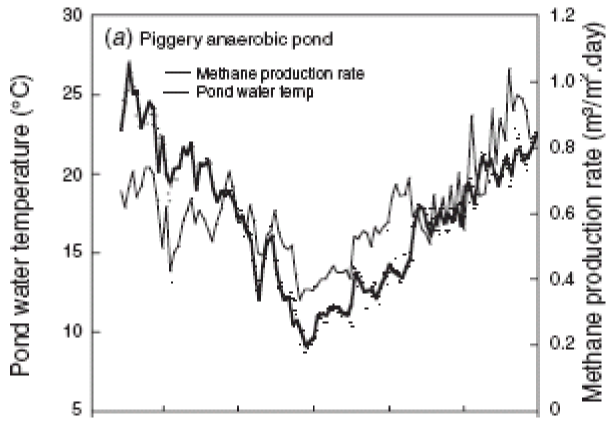

Figure 1 Areal methane production and average daily pond surface water temperature of a New Zealand piggery anaerobic pond, monitored between January 2006 and January 2007 (Source: Craggs et al. 2008).

VS loading rate also impacts on CH_4 emissions from poultry manure. Techniques such as solid separation before the manure enters the pond system can reduce the amount of CH_4 emission. Globally, only limited studies (Safley & Westerman 1988, 1989) examined anaerobic lagoon CH_4 emissions from poultry manure, and no NZ based studies were found. Anaerobic digester studies (Webb & Hawkes 1985; Bujoczek et al. 2000) found ammonia accumulation within the system reduces the rate of anaerobic fermentation and lowers CH_4 emissions where high solid loading rates are digested. It is unclear if ammonia would significantly inhibit VS conversion rates in poultry anaerobic lagoons. Loading rates of most anaerobic lagoons are low (0.06-0.08kgVSm^{-3}d^{-1};Safely & Westerman 1988) compared with that of digesters.

Table 3.14 Poultry manure anaerobic lagoon CH_4 emissions

Reference	AWMS	VS loading rate kg VS M^{-3} day^{-1}	CH_4 production $m^3 kg\ VS^{-1} day^{-1}$
Safely & Westerman (1988)	Poultry manure post anaerobic digestion (54.4% VS reduction)	0.16	0.894*
Safely & Westerman (1988)	Caged layers – flushed daily	0.02	0.972*
Safely & Westerman (1989)	Poultry manure post anaerobic digestion (54.4% VS reduction)	0.462	0.095

In contrast to CH_4 emissions, manure stored as anaerobic slurries (lagoons), results in low N_2O emissions (Oenema et al. 2005). In anaerobic lagoons the lack of available oxygen limits the nitrification reaction, and much of the N input is thought to be denitrified by microbial and/or chemical denitrification resulting in dinitrogen (N_2) emissions (Harper 2004). The current IPCC guidelines recommend an EF_3 value of 0.01 kg N_2O-N kg^{-1} Nex. However, the proposed IPCC (2006) guidelines for anaerobic ponds suggest zero (EF_3 of 0 kg N_2O-N kg^{-1} Nex) N_2O emissions. No NZ or international data on N_2O emissions from poultry anaerobic lagoons are available. Studies from anaerobic lagoons from other livestock manure have shown a range in results. Harper et al. (2000) did not detect N_2O emissions from swine anaerobic lagoons or from the sludge layer of the lagoon. However, in a later study Harper et al. (2004) noted an N_2O emission rate of 0.3 and 0.4 kg N_2O ha^{-1} d^{-1} from anaerobic lagoon treating farrow to finish and farrow to wean effluent respectively (Casey et al. 2006).

3.9 Emissions following manure application to agriculture soils

IPCC (1996) methodology assumes all manure produced by the poultry industry is applied to agricultural soils. In the NIR, N_2O emissions from agricultural or managed soils are calculated as direct emissions from application of manure to soils and indirect emissions from volatilised NH_3 and NOx and leached/runoff of NO_3^- and subsequent deposition of these agriculturally derived N into another environment (IPCC 2006).

*assumes biogas contains 64.8% CH_4 (Safely & Westerman 1989)

New Zealand estimates suggest that approximately 90–92% poultry manure/litter is applied to pasture soils, 3% is further composted and the remaining 5–7% is used for general farming and gardening purposes (PIANZ & EPFNZ 2010). The amount of N applied to the soils is calculated from the amount entering a given AWMS and the amount volatalised during the land application (Equation 7) .

$$F_{AW} = N_{AW} \times (1\text{-}Frac_{gasm,}) \qquad \text{(Equation 7)}$$

where: F_{AW} = the total amount of animal manure N applied to soils from waste management systems (other than discharge to pasture or paddock) after adjusting for indirect emissions that occur once the manure has been applied to soils; N_{AW} = the amount of animal manure N in each waste management system minus the N applied directly to pasture and paddock; and $Frac_{GASM}$ = Fraction of total animal manure emitted as NOx or NH_3 (NZ specific default value 0.1).

While Equation 7 takes account of N lost through volatilisation during the land application, it does not include N lost during the storage and treatment of poultry manure. Gaseous loss of N from effluent stored or treated over a period can be a major pathway of N movement depending upon storage conditions (McCrory & Hobbs 2004). Mahimairaja (1993) reported 11–77% N loss from poultry manure depending upon manure characteristics and treatment techniques. Kithome et al.(1999) suggested 47–62% N loss from volatilisation during 25 days of composting, while De Laune et al.(2004) reported 53% N loss over 1 yr from composted poultry manure. Kelleher (2001) notes the NH_3 loss from unmanaged manure can range from 47 to 62% of the total N. Thus the current methodology may overestimate the amount of N applied to NZ agricultural soils from poultry manure and subsequent N_2O emissions. The proposed 2006 IPCC guidelines take account of the N loss during treatment and storage by introducing a new EF ($Frac_{LossMS}$) (Table 3.15). For poultry manure recommended value for $Frac_{LossMS}$ is 40-55% of the total excreted N (IPCC 2006).

Table 3.15 Default values for total N loss from manure management of poultry AWMS (OPCC 2006)

AWMS	$Frac_{LossMS}$ (%)	$Frac_{LossMS}$ (Range %)
Poultry without litter	55	40–70
Anaerobic lagoon	40	25–75
Poultry with litter	40	10–60

Quantification of N losses during treatment and storage of poultry manure in NZ is required to ensure an accurate N budget is compiled within the inventory calculations.

3.9.1 Direct N_2O emission's agricultural soils

In New Zealand effluent irrigation to pasture contributes considerable N_2O emissions (Saggar et al. 2004a; Wang 2004). Applied manure increases soluble C and mineral N that can stimulate microbial activity within the soil, resulting in increased N_2O emissions (Bhandral et al. 2007b). Of the N applied in poultry manure to agricultural soils, the IPCC methodology assumes a proportion (EF_3) will be emiitted as N_2O and reported as direct agricultural soil emissions (Equation 8).

$$N_2O_{\text{direct from AW-N}} = F_{AW} * EF_3 * 44/28 \qquad \text{(Equation 8)}$$

where: F_{AW} = the total amount of animal manure N applied to soils from waste management systems (other than direct application to pasture and paddock) after adjusting for indirect emissions that occur once the manure has been applied to soils; EF_3 = proportion of direct emissions from N input to soil (0.01 kg N_2O-N/kg N, NZ specific for all animal manure).

EF_3 can vary depending upon soil and environmental parameters such as soil moisture, texture, temperature, and the amount and composition of applied manure N (Akiyama et al. 2004; Saggar et al. 2004a). Soil microbial activity is often optimal above 15°C and below 40°C (McLaren & Cameron 1996). N_2O emissions will be low in saturated soils because of complete denitrification to N_2. However, emissions rapidly increase when soil moisture is between 65 and 95% water-filled pore space (WFPS) (Saggar et al. 2004d; Phillips et al. 2007). The soil texture can affect the drainage characteristics or WFPS of soils. Results from laboratory studies have indicated that N_2O emissions from poorly drained NZ soils were 2–5 times more than N_2O under free-draining soils (de Klein & Ledgard 2005).

The method of manure (dry or wet) application can impact on biological, chemical and physical soil processes because of changes in soil pH and WFPS (Velthof 2003). During effluent irrigation, liquid replaces soil air and generates anoxic conditions (Russell 1996). Bhandral et al.(2007a) found that the oxygen diffusion rates through the soil immediately decreased with the application of a slurry, resulting in conditions conducive to N_2O formation.

The composition of the manure (NO_3^-, NH_4^+ and organic N concentrations) as well as time in storage will also affect N_2O emissions from soils. Thornton et al. (1998) (Table 3.16) studied different manure treatment techniques (composted vs fresh poultry manure) and found that fresh poultry manure releases more than twice the N_2O emissions of composted manure.

Table 3.16 Seasonal average N_2O emissions from manure sources (CNT = control with no N applied URE urea (FPL) fresh poultry litter and CPL = composted poultry litter. (Source: Thornton *et al* 1998)

Treatment	N_2O emission ($ng\ N_2O\text{-}N\ m^{-2}\ s^{-1}$)	NO emission ($ng\ NO\text{-}N\ m^{-2}\ s^{-1}$)	N_2O loss ($kg\ N\ ha^{-1}$)	NO loss ($kg\ N\ ha^{-1}$)
FPL	32.22 (35.97)	8.33 (2.52)	3.87	0.97
URE	24.58 (17.66)	11.67 (4.51)	2.96	1.36
CPL	13.70 (13.24)	4.00 (1.00)	1.64	0.47
CNT	4.26 (2.90)	1.33 (0.58)	0.51	0.16

The EF_3 values reported in the literature for various manures applied to soils are summarised in Table 3.17.

Table 3.17 N_2O emissions for applications of poultry manure to land

Livestock type	Manure type	Country	Application rate	N_2O-N emissions ($kg\ N/ha^{-1}$)	% of total N applied	Reference
IPCC	All manure	NA	NA		1% (0.3 – 3%)	IPCC (1996, 2006)
NZ specific	All Manure	New Zealand	NA		1%	Kelliher & de Klein (2006)
	All manure	NA			0.6%	FAO & IFA (2001)
Poultry	Fresh poultry litter	USA	336 kg available N ha^{-1}	3.87	1.15% available N	Thornton et al. (1998)
Poultry	Composted poultry litter	USA	336 kg available N ha^{-1}	1.64	0.49% available N	Thornton et al. (1998)
Layer	manure belt	Netherlands	100 mg N kg $soils^{-1}$	2.5	1.9	Velthof et al. (2003)
Layer	Dried	Japan	15g Nm^{-2}		1.14-1.23%	Akiyama & Tsuruta (2003)
Meat chicken	slatted floor	Netherlands	100 mg N kg $soils^{-1}$	1.1	0.5	Velthof et al. (2003)
Ducks	Straw	Netherlands	100 mg N kg $soils^{-1}$	1.2	0.6	Velthof et al. (2003)

Nitrous oxide emissions from agricultural soils in NZ have been extensively studied (e.g., Sherlock et al. 2002; de Klein et al. 2003; Saggar et al. 2004a, 2007; Kelliher & de Klein 2006). However, no NZ study has examined N_2O emissions from the land application of poultry manure. The current NIR uses a single country-specific default EF_3 value for the application of all animal waste products to land. The NZ–specific value for EF_3 (0.01 kg N_2O-N kg^{-1} N) (Kelliher de Klein 2006) has been developed based on three NZ studies that yielded average (geometric) values equal to 0.013, 0.0232 and 0.0036 kg N_2O-N kg^{-1} N. The average of these three values is 0.0103 kg N_2O-N kg^{-1} N. Consequently, on average, the data are thought to support the NZ-specific value for EF_3 (Kelliher et al. 2007). It should be noted that these values are based on the application of animal urine to the soils and do not specifically represent land application of poultry manure.

Given the wide range in poultry manure composition, care should be taken in applying a blanket approach to estimating emissions and assuming the same emission rate for all manure sources, e.g., cattle, poultry and pigs as concentration of inorganic N, easily mineralised N and C will vary between manures (Redding 2010). Bhandral et al. (2007b) found between 0.3 to 2.2% of N in various farm effluents applied to pasture soil was emitted (Table 3.18).

Table 3.18N_2O emissions from treated farm dairy effluent (TFDE), untreated farm dairy effluent (UFDE), treated piggery farm effluent (TPFE) and treated meat effluent (TME)) following the autumn and winter application on Manawatu sandy loam (Source: Bhandral et al. 2007b)

Type of Effluent	N added through effluent (kg N ha^{-1})		N emitted (kg N ha^{-1})		% of added N emitted	
	Autumn	Winter	Autumn	Winter	Autumn	Winter
FDE	21.8	13.0	0.382	0.102	2.0	0.8
UFDE	61.0	49.3	0.447	0.153	0.7	0.3
TPFE	27.5	23.1	0.585	0.130	2.2	0.6
TME	39.5	33.8	0.456	0.286	1.2	0.8
Water	0.0	0.0	0.207	0.101	–	–
Control	–		0.193	0.072		
LSD (0.05%) Treatments n = 4			0.023	0.036		
LSD (0.01%) Treatments n = 4			0.032	0.050		

Akiyama and Tsuruta (2003) observed that poultry manure from caged layer hens produced a higher N_2O (1.14-1.23% of N applied) than swine manure (0.31 – 0.41% of N applied). However, Velthofet al. (2003) found higher emissions from pig manure (7.3 – 13.9% of the N applied) compared with poultry manure (0.5 – 1.9%).

Unlike dairy farms where manure is applied to fields located under the same management as where the manure is produced, poultry manure is often applied to land outside the control of the industry. This removes the industry's ability to apply mitigation technologies such as the application of DCD, and limits the development of mitigation strategies available to the poultry industry to reduce their agricultural soil emissions.

3.9.2 Indirect N_20 emissions from agricultural soils

Uric acid and undigested proteins are the two main N components in poultry manure that cause ammonia emissions and nitrate leaching and runoff (Nahm 2003). Mineralization of organic N (uric acid) is a two-stage process consisting of ammoniafication and nitrification (Edwards & Daniel 1992). Both reactions can result in indirect N_2O emissions recorded in NIRs. The EFs applied to indirect emissions within the NZ poultry industry are reviewed below.

3.9.2.1 *Ammonia volatilisation from poultry*

Significant ammonia is volatilised in animal production houses and in manure management operations (Moore et al. 1995; Thornton et al. 1998) as well as after land application. The volatilisation of ammonia has been attributed to microbial decomposition of nitrogenous compounds, principally uric acid, in poultry litter/manure (Blake & Hess 2001). The excreted N undergoes hydrolysis catalysed by enzymes resulting in the release of NH_4^+ and carbonate (CO_3^{2-}) ions (Saggar 2008). Once formed, the free ammonia will be in one of two forms: NH_3 (ammonia) or the ammonium ion (NH_4^+), the ratio will vary depending on the pH of the litter (Blake & Hess 2001). NH_3 is subject to loss through volatilisation (Saggar 2008).

$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ (pka 9.24) (Equation 9)

The fraction of N that volatilises from livestock manure depends on several variables. High volatilisation rates have been recorded at high temperatures, low soil cation exchange capacity, and high rates of air movement across the application area (Edwards & Daniel 1992). Increasing the pH also results in an increase in ammonia production, while a low C:N ratio contributes to ammonia loss (Gray et al. 1971; Kelleher et al. 2002).

In animal housing high ammonia concentrations can have a negative effect on bird health and growth (Latshaw & Zhao 2011). Emmisions of ammonia measured in a number of studies from animal housing and manure storage are given in Table 3.19.

While ammonia emissions from animal housing can be significant (IPCC 2006), these emissions are at present not directly reported within the NIR using the existing IPCC methodology. However, it could be argued that these emissions are currently incorporated into indirect emissions from agricultural soils (Equation 10) as the quantity of N being applied to soils has not been adjusted for N loss from AWMS. As mentioned earlier, this results in an excess amount of N being recorded as being applied to agricultural soils through indirect emissions. The 2006 IPCC guidelines provide a clearer assessment of indirect emissions from AWMS by outlining methodology to account for these emissions. Further work is required to remove the uncertainty surrounding the existing IPCC methodology for emissions from this source.

Table 3.19 Ammonia emission factors from poultry housing (AU= Animal Unit or 500kg of animals) (source Roumeliotis and Van Heyst 2008)

Type of operation	Country	Study	House and manure system	EF (g/d per animal unit)
Meat chicken	England, the Netherlands, Denmark, Germany	Groot Koerkamp et al. (1998)	Litter floor	53 to 199
Meat chicken	Europe	Asman (1992)	Litter floor	77
Meat chicken	Europe	Van Der Hoek (1998)	Litter floor	178
Meat chicken	Ireland	Hyde et al. (2003)	Litter floor	150
Meat chicken	Germany	Oldenburg et al. (1992)	Litter floor	182
Meat chicken	Slovenia	Amon et al. (1997)	Litter floor	14–194
Meat chicken	UK	Demmers et al. (1999)	Litter floor	57.2
Meat chicken	UK	Misselbrook et al. (2000)	Litter floor	149
Meat chicken	UK	Phillips et al. (1995)	Litter floor	204–223
Meat chicken	UK	Sneath et al. (1996)	Litter floor	178
Meat chicken	UK	Wathes et al. (1997)	Litter floor	204–220
Meat chicken	USA	Gates et al. (2007)	Litter floor	0–768
Meat chicken	USA	Wheeler et al. (2006)	Litter floor	390.7
Meat chicken	USA	Lacey et al. (2003)	Litter floor	307
Layer	England, the Netherlands, Denmark, Germany	Groot Koerkamp et al. (1998)	Batter cage	15–224
Layer	England, the Netherlands, Denmark, Germany	Groot Koerkamp et al. (1998)	Perchery, deep pit	177–261
Layer	Germany	Hartung & Phillips (1994)	Battery cage	72
Layer	UK	Nicholson et al. (2004)	3-tier cage	64.8
Layer	UK	Nicholson et al. (2004)	Deep pit	33.6–196.8
Layer	UK	Phillips et al. (1995)	Battery cage	168–295
Layer	UK	Phillips et al. (1995)	Perchery	192–240
Layer	UK	Wathes et al. (1997)	Deep pit	220
Layer	USA	Heber et al. (2005)	High-rise	468 ± 256
Layer	USA	Heber et al. (2005)	High-rise	342 ± 136
Layer	USA	Jacobson et al. (2004)	High-rise	200–500
Turkey	Europe	Asman (1992)	—	126
Turkey	Europe	Van Der Hoek (2005)	—	113
Turkey (grow out)	USA	Gay et al. (2005)	Litter floor	120.5
Turkey (brooder)	USA	Gay et al. (2005)	2 rows, litter floor	7.2
Poultry	UK, the Netherlands, Europe	Sutton et al. (1995)	—	162–338
Poultry	USA	Battye et al. (1994)	—	243

The current method for calculating N_2O emissions from ammonia volatilisation is given in (Equation 10). The methodology applies a $Frac_{GASM}$ emission factor which is the quantity of N lost through volatilisation during the land application process. An EF_4 factor is then to applied to calculate the proportion of N that is deposited back to the soils where N_2O forming processes convert the N to N_2O.

$$N_2O_{(G)} = [(N \times Nex) \times Frac_{GASM}] \times EF_4 \times 44/28 \qquad \text{(Equation 10)}$$

where: $N_2O_{(G)}$ = N_2O produced from atmospheric deposition; N= Population of poultry; Nex= Annual average N excretion per head; $Frac_{GASM}$ = Fraction of total animal manure emitted as NOx or NH_3. EF_4 = proportion of nitrogen input that contributes indirect emissions from volatilised N (IPCC default 0.01 kg N_2O-N/kg NH_4-N & NOx-N deposited).

Volatilisation rates from agricultural soils are site-specific, as the rate can vary in accordance with soil and climate factors such as soil pH, soil moisture, soil texture, soil cation exchange capacity, temperature and wind velocity (Saggar et al. 2004a).

NZ has recently developed a NZ-specific value for $Frac_{GASM}$ based on international and New Zealand-based research review recommendations of Sherlock et al. (2009). MfE (2010) noted that the variation in $Frac_{GASM}$ from the IPCC to the NZ value was primarily due to the large proportion of animal waste deposited directly to pastures by grazing animals (Pasture/Range and Paddock- derived N). While this is a legitimate assumption at a national level, within the NZ poultry industry a large proportion of effluent is applied to land though surface and subsurface application methods. These have the potential to impact significantly on volatilisation rates. Surface application of manure can result in high NH_3 volatilisation loss due in part to a high rate of N mineralisation. Also a very low volatilisation is reported when manure is injected or incorporated immediately into the soil (Meisinger & Jokela 2000).

Manure N losses before land application also need to be taken into account (Lockyer & Pain 1989). Brinson et al. (1994) noted that composted poultry litter had a lower rate of N mineralization than fresh poultry litter and, therefore, resulted in lower NH_3 losses (0 –0.24% of N in composted manure) than from fresh litter (17–31% of N in fresh manure). Ammonia volatilisation rates from poultry manure reported in national and international literature are summarized in Table 3.20.

Table 3.20% of total N lost through ammonia volatilisation from agricultural soils

Live stock type	Manure type	Country	Ammonia+ Uric acid N loss (%)	% of total N applied	Reference
IPCC	All manure			20%	IPCC (1996, 2006)
NZ specific	All Manure	New Zealand		10%	Sherlock et al. (2009)
Aust Specific	All Manure	Australia		21%	2008 NIR value MFE (2010)
UK specific	All Manure	UK		20%	2008 NIR value MFE 2010
Poultry	Subsurface application	USA	NA	4–31%	Schilke-Gartley & Sims (1993)
Poultry	Conservation tillage	USA	9.9 – 101	3.3 – 22.3	Sharpe et al. (2004)
Poultry Manure	Surface Application			35–65%	MAFF 1999
Poultry	No tillage	USA	13.4 – 95.1	4.1 – 23.9	Sharpe et al. (2004)
Poultry	Immediate incorporation into soil		NA	3%	Sims & Wolf (1994)
Poultry	Surface application			20%	Sims & Wolf (1994)
Poultry	Surface application (11 days post application			37%	Wolf (1988)
	Incorporated (11 days post application)			1–8%	Wolf (1988)
Poultry	Surface applied 10 days			48%	Giddbens and Rao (1975)
	Surface applied 5 day trail Clay soils			49–70%	Crane et al. (1981)
	Surface applied 5 day trail Sandy soils			58–75%	Crane et al. (1981)
	Surface application Sandy loam			11%	Giddens & Rao (1975)
Turkey	Litter Open field study			7%	Nathan & Makzer (1994)
Poultry	NA	UK	35%		Chambers (1998)
Meat chicken house	Fresh manure	USA		17–31%	Brinson et al. (1994)
Meat chicken House	Composted manure	USA		0 – 0.24	Brinson et al. (1994)
Poultry	NA	UK	45%		Misselbrook et al. (2000)
Layer hens	Under cage storage pumped as a Slurry	Netherlands	83.1	45.4	Lockyer & Pain (1989)
Layer	Slurry	Netherlands	72.0	38.2	Lockyer & Pain (1989)
Layer	Dried on belts	Netherlands	21.4	56.5	Lockyer & Pain (1989)
Meat chicken	Litter – straw	Netherlands	37.2	7.2	Lockyer & Pain (1989)

3.9.2.2 *N_2O emissions from redeposited volatilized-N (EF_4)*

Of the N that volatilises from poultry manure, the IPCC methodology assumes that a percentage will be deposited back to land resulting in N_2O emissions (EF_4). The IPCC (1996) guidelines recommend an EF of 0.01 kg N_2O-N kg^{-1} NH_3-N and NO_x emitted. However, there is considerable uncertainty around this EF value. The IPCC (1996) guidelines provide a range 0.002 – 0.02 kg N_2O-N kg^{-1} NH_3-N and NO_x,while the proposed IPCC (2006) guidelines extend the range from 0.002 to 0.05 kg N_2O-N kg^{-1} NH_3-N and NO_x.No references are provided for the origin of this EF and no NZ-based studies were noted.

3.10 Indirect N_2O emissions from leaching/runoff of NZ poultry manure N (EF_5)

The IPCC (2006) notes that inorganic N sources in or on the soils (mainly in the form of NO^-_3) may bypass biological retention in the soil or vegetation by transport into overland water flows (runoff) as well as through leaching. As with emissions from volatilisation, the deposition of the N into a receiving environment may result in N_2O emissions. As a result the effects of leached N are accounted for in the NIR using Equation 11.

$$N_2O = (MS \times Nex \times N) \times Frac_{leach} \times EF_5 \times 44/28 \qquad \text{(Equation 11)}$$

where: N = population; N_{ex} = annual average N excretion per head; MS = proportion of manure applied to pastures (kg); $Frac_{leach}$ = fraction of N input to soils that is lost through leaching and runoff (0.07, NZ specific fraction); EF_5 = proportion of N input that contributes to indirect emissions from leached N.

Poultry manure N can undergo rapid nitrification on its addition to soil, making it susceptible to N-leaching (Sallade & Sims 1993). The application of manure to land can convert NH_4-N plus uric acid N to nitrate N (NO_3^-) (Chambers et al. 1999). However, for poultry manure the conversion may be inhibited when conditions favour volatilisation (Edwards & Daniel 1992). Thus volatilisation losses may significantly reduce the quantity of N available for plant uptake and leaching. However, Nex is currently included in the IPCC leaching/runoff methodology. As mentioned earlier, this results in overestimating the N available for leaching within soils.

The movement of NO_3^- through the soil profile is closely linked to the drainage characteristics or porosity of the soil, the application method, rates (Laurenson et al. 2006), timing (Edwards & Daniel 1992), the slope of the application area, and the amount of water moving through a system (Sallade & Sims 1993). Quinn and Stroud (2002) noted that a higher rate of N loss is associated with high rainfall environments in NZ pastoral systems. Shepherd and Bhogal (1997) found between 1 and 97% of total N from meat chicken litter can leach depending on the time of application and the quantity of N being applied. They concluded that the high loss was probably the result of the cumulative effect of residual N storage within the soil from previous applications as well as the timing of the second application (winter).

The IPCC (1996) guidelines outline that $Frac_{leach}$ can range between 0.1 and 0.8 kg Nkg^{-1} fertiliser (or manure) N. The guidelines recommend a default value of 0.3. New Zealand, however, has developed a country-specific default value using the OVERSEER® nutrient budget model that takes into account NZ climate, soil drainage characteristics and animal/crop management systems and agricultural practices and concluded that a mean $Frac_{Leach}$ value of 0.07 kg N/kg fertiliser or manure N represented NZ agricultural conditions (Thomas et al. 2005).

Poultry manure was not included in the study by Thomas et al. (2005). Furthermore, this study did not examine the application of animal litter or manure to soils but instead focused mainly on grazing animals and the application of fertilizers to land, which leads to uncertainty in the $Frac_{Leach}$ value for the application of animal manures to land. In a 3-year study, Chinkuyu et al. (2002) compared the applications of layer hen manure and UAN fertilizer. They found that under identical loading rates (168 kg-N/ha) the application of manure resulted in significantly less NO_3-N loss than the loss from fertiliser application. Of the $Frac_{leach}$ the methodology assumes a proportion will be deposited back into another environment, resulting in N2O emissions (EF5). This EF5 has been developed to incorporate emissions as a result of the deposition of anthropogenic sourced N in: 1) groundwater and surface water drainage (EF5g); 2) rivers (EF5r); and 3) estuaries (EF5E). The IPCC note that there are considerable uncertainties behind the methods used to establish the EF5 value (IPCC 1996; 2006).

Table 3.21 demonstrates the leaching or runoff rates found in international literature from the application of poultry litter as no NZ based literature was identified.

Table 3.21 Summary of leaching and runoff rates from poultry manure applied to soils

Live stock type	Manure type		Land use / soils	% of total N applied	Reference
		Leaching/ runoff			
IPCC	All N applications	International		30% (10–80%)	IPCC (1996, 2006)
NIR	All N applications	NZ		7%	Thomas et al. (2005)
NIR	Australia specific NIR	Australia		30%	2008 NIR value MFE (2010)
NIR	UK specific NIR	UK		30%	2008 NIR value MFE (2010)
		Leaching			
	Caged	USA	Loamy sand soils	26%	Sallade & Sims (1994)
	Meat chicken litter	UK	Loamy sand 4–6% clay	1–97%	Shepherd & Bhogal (1998)
		Runoff			
	Manure Litter	USA	Grazed pasture	1.4% 1.1%	Edwards et al 1996
	litter	USA	Corn-winter rye	1.89%-2-03	Hall (1994); Wood et al. (1999)
	Litter	USA	Cotton	1.9	Vories et al. (2001)

Currently, the IPCC (1996) default value is being applied in the NZ NIR. However, the proposed IPCC (2006) methodology provides an updated EF_5 value from 0.025 to 0.0075 kg N_2O-N/kg N leached or in runoff water, based on the findings of recent research (IPCC 2006). This reduction resulted in part from a NZ-based study (Clough et al. 2006) where N_2O emissions from a spring fed river in the Lincoln area were examined and an EF_{5r} value of <0.0005 kg N_2O-N/Kg N proposed for NZ.

4 SURVEY INFORMATION

Aproximately 98.7% of meat produced within New Zealand is produced from meat chickens raised by PIANZ members. This amounts to approximately 140,000-144,000 tonnes of meat chicken meat per annum. The survey information was collected from 4 companies within PIANZ and accounts for 100% of chicken meat production.

Aproximately 0.3% of meat produced within New Zealand is produced from turkeys and are members of PIANZ. This amounts to approximately 1300 – 1500 tonnes of turkey meat per annum. The survey information was collected from 3 companies within PIANZ and accounts for 100% of turkey meat production in New Zealand.

Aproximately 1% of duck meat produced within New Zealand is produced from PIANZ members. This amounts to approximately 1100 – 1500 tonnes of duck meat per annum. The survey information was collected from 2 companies within PIANZ and accounts for 100% of duck meat production in New Zealand.

Aproximately 3,015,261 layer hens (i.e. 90% of the national flock size from the 2009-2010 calendar year[2] was estimated to be housed in commercial production systems. The information collected from this survey accounted for approximately 81.5% of the commercial egg industry (i.e. 2,458,912 birds). This amassed a total of 57 survey respondents (i.e. including farms which house hens for egg production in single or multiple production systems).

The following information summarizes information found from surveying the commercial meat chicken, turkey meat duck meat and layer industries in New Zealand and consisted of the following main topics for meat chickens, turkey meat, duck meat and layer hens:

- placement statistics(which includes processing for poultry meat production)
- litter management
- information on poultry feeds

4.1 Meat chicken placement and processing statistics

The most common meat chicken breed utilized in New Zealand for meat chicken production is the Ross bird. Approximately 96.9% of birds grown for meat production are from this breed. The remaining 3.1% of birds are Cobb bred birds.

Approximately 84,784,736 birds in the 2009 to 2010 financial year were placed in production systems across the entire meat chicken meat industry. This accounted for a total of 82,076,564 birds being processed for chicken meat. This comprises a total of 95.1% (or 78,084,349 birds) that were processed from barn production systems and 4.9% (or 992,215 birds) that were processed from free-range production systems.

[2]It was assumed that up to 10% of the national flock size is from backyard and small semi-commercial flocks that are not EPFNZ members.

Barn production mortality was 3.20% ± 0.004, whereas free range mortality was 2.99% ± 0.005. The overall industry mortality figure was approximately 3.19% (weighted average)[3].

The average number of days to grow a meat chicken required approximately 36 days and the average number of birds that were grown within thefinancial year totaled 8,362,330 birds (this figure is equivalent to the number of meat chickens it would take if they were grown for a full year –see section 7 for more information on this estimation).

4.2 Meat chicken litter management

100% of the bedding material consists of wood shavings. It has been estimated that approximately 18,100 tonnes of bedding material is utilized in the meat chicken industry. Approximately 154,343 tonnes of used litter is produced from the meat chicken industry, with 7,420 tonnes (or nearly 5% of the total amount of used litter) produced from free range operations whilst the remaining 146,923 tonnes (or 95% of the litter) is produced from barn production systems.

The meat chicken industry generally removes litter from their operations 6.1 times per annum/shed (weighted average)[3]. The used litter that is collected is generally spread on fields such as general land/farming applications (71%), spread on dairy pasture (21%) and spread on mushroom/maize fields (8%). This means that meat chicken litter is eventually spread on pasture (i.e. 100%).

It is practice for used litter collection companies to generally spread used litter or fertilizer on land almost immediately after collection. However, in situations when it is raining, wet or if the demand for the used litter is not there, used litter is generally collected and dry stored until it can be used. We also note that the use of poultry manure is driven by the cost of oil (where if the cost of oil becomes more affordable to make synthetic fertilizers, this means the demand for used poultry litter will decrease, and vice-versa).

4.3 Information on meat chicken feed

Approximately 95.1% of the meat chicken industry is fed 4 feeding phases. Free range meat chickens are generally fed between 2-3 different types of feed. This is due to the fact that free range birds are generally grown to a smaller size as conventional barn produced meat chickens. The following information is based upon a weighted average[1] of 4 feeding phases. Please note that the ingredients used in manufacturing meat chicken feed will primarily depend on the availability and cost of feed ingredients. Furthermore, each feed is generally manufactured to ensure that the meat chickens are receiving the necessary components of a diet to promote growth and/or performance.

Phase 1:
Meat chickens in the first phase of feeding are fed 503.59 grams over 12.4 days. The metabolisable energy (ME) within this feed is 12.37 MJ/kg, the Gross energy (GE) is 16.30 MJ/kg, the crude protein (CP) of the diet is 23.93%, and the digestibility (DE) of this feed is

[3] The weighted average is determined through weighting each companies total number of processed birds to the total number of birds produced from all PIANZ members.

approximately 75.85%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the meat chicken industry[3].

Table 4.1 Phase 1 meat chicken feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-55	44.1
Soya meal	10-35	25.9
Maize	0-65	9.9
Meat & Bone meal	5-15	8.0
Sorghum	0-25	4.8
Vitamins/minerals and enzymes	0-3.5	2.0
Oils/Fats	1-2.5	2.0
Blood meal	0-2	0.9
Barley	0-5	0.8
Amino Acids	0.5-1	0.7
Faba bean	0-4	0.6
Broll	0-7	0.3

Phase 2:

Meat chickens in the second phase of feeding are fed 855.63 grams over 9.5 days. The metabolisable energy (ME) within this feed is 12.53 MJ/kg, the Gross energy (GE) is 16.50 MJ/kg, the crude protein (CP) of the diet is 21.42%, and the digestibility (DE) of this feed is approximately 75.96%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the meat chicken industry[3].

Table 4.2 Phase 2 meat chicken feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-65	50.3
Soya meal	2-25	19.6
Maize	0-60	9.5
Meat & Bone meal	6-15	7.5
Sorghum	0-25	5.7
Oils/Fats	0-4	2.3
Vitamins/minerals and enzymes	0-3	1.8
Broll	0-30	1.1
Blood meal	0-2	0.8
Faba bean	0-5	0.7
Amino Acids	0-1	0.7
Barley	0-5	0.0

Phase 3:

Meat chickens in the third phase of feeding are fed 1090.02 grams over 8.5 days. The metabolisable energy (ME) within this feed is 12.67 MJ/kg, the Gross energy (GE) is 16.65

MJ/kg, the crude protein (CP) of the diet is 20.58%, and the digestibility (DE) of this feed is approximately 76.07%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the meat chicken industry[3].

Table 4.3 Phase 3 meat chicken feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-65	57.6
Soya meal	5-25	17.6
Maize	0-15	8.6
Meat & Bone meal	5-10	7.2
Sorghum	0-15	3.3
Oils/Fats	0-3	2.3
Vitamins/minerals and enzymes	0-3	1.2
Faba bean	0-6	0.8
Blood meal	0-2	0.8
Amino Acids	0-1	0.5
Broll	0-5	0.1

Phase 4:

Meat chickens in the fourth phase of feeding are fed 1193.18 grams over 5.5 days. The metabolisable energy (ME) within this feed is 12.61 MJ/kg, the Gross energy (GE) is 16.48 MJ/kg, the crude protein (CP) of the diet is 19.13%, and the digestibility (DE) of this feed is approximately 75.31%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the meat chicken industry[3].

Table 4.4 Phase 4 meat chicken feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-70	60.2
Soya meal	10-25	15.7
Maize	0-75	8.7
Meat & Bone meal	2-15	6.7
Sorghum	0-15	3.4
Oils/Fats	0-3	2.3
Vitamin/minerals and enzymes	0-2	1.1
Faba bean	0-10	0.8
Amino Acids	0-1	0.5
Blood meal	0-5	0.5
Broll	0-5	0.1

4.4 Turkey placement and processing statistics

The most common turkey used in New Zealand for turkey meat production are from British United Turkey (B.U.T). Approximately 90.9% of the birds grown for meat production are from B.U.T. The remaining 9.1% of the birds are from an older breed that had originally been imported stock from Australia (called 'Australian White'). Because the last Australian White stock was imported to New Zealand approximately 30-40 years ago and thus have continued to be bred in NZ, these birds are referred to as 'N.Z. White'.

Approximately 289,400 birds in the 2009-2010 financial year were placed in production systems across the entire turkey meat industry. This accounted for a total of 273,120 birds being processed for turkey meat. This comprises a total of 89.4% (or 244,120 birds) that were processed from barn production systems and 10.6% (or 29,000 birds) that were processed from free-range systems.

Mortality was lower in barn produciton systems (5.44% ± 0.002) then compared to free range production systems (7.17% ± 0.012). The overall industry mortality figure was approximately 5.63% (weighted average)[3].

The average number of days required to grow a turkey required approximately 68 days and the average number of birds that were grown within this financial year totaled 53,916 birds (this figure is equivalent to the number of turkeys it would take if they were grown for a full year – see section 7 for more information on this estimation).

4.5 Turkey litter management

100% of the bedding material consists of wood shavings (where in some cases, it may also consist of saw dust). It has been estimated that approximately 200 tonnes of bedding material is utilized in the turkey industry. Approximately 948 tonnes of used litter is produced from the turkey industry, with 28 tonnes (or nearly 3% of the total amount of used litter) produced from free range operations and the remaining 920 tonnes (or 97% of the litter) are from barn production systems.

The turkey industry generally removes litter from their operations 3.2 times per annum/shed (weighted average)[3]. The used litter that is collected is generally sold as a fertilizer material (51%) or spread on land (49%). Generaly poultry manure sold as a fertilizer will eventually be spread on land (i.e. 100% is spread on pasture).

It is practice for used litter collection companies to generally spread used litter or fertilizer on land almost immediately after collection. However, in the situations when it is raining, wet or if the demand for the used litter is not there, used litter is generally collected and dry stored until it can be used. We also note that the use of poultry manure is driven by the cost of oil (where if the cost of oil becomes more affordable to make synthetic fertilizers, this means the demand for used poultry litter will decrease, and vice-versa).

4.6 Information on turkey feed

Approximately 85.3% of the turkey industry is fed 4 feeding phases and the following information is based upon a weighted average[3] of these 4 phases. Note that the ingredients used in manufacturing turkey feed will primarily depend on the availability and cost of the ingredients. Furthermore, each feed is generally manufactured to ensure that the turkeys are receiving the necessary components of a diet to promote growth and/or performance.

Phase 1:

Turkeys in the first phase of feeding are fed 542.0 grams over 15.3 days. The metabolizable energy (ME) within this feed is 11.56 MJ/kg, the Gross energy (GE) is 15.61 MJ/kg, the crude protein (CP) of the diet is 30.54%, and the digestibility (DE) of this feed is approximately 74.49%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the turkey industry[3].

Table 4.5 Phase 1 turkey feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-45	35.0
Soya meal	0-45	30.2
Barley	0-35	25.6
Meat & Bone meal	0-10	3.3
Vitamins/minerals and enzymes	0-2	1.6
Oils/Fats	0-3	0.9
Oats	0-10	0.7
Blood meal	0-2	0.7
Peas	0-9	0.7
Fishmeal	0-5	0.7
Amino Acids	0-1	0.5
Limestone	0-1	0.1
Dicalcium Phosphate	0-1	0.1

Phase 2:

Turkeys in the second phase of feeding are fed 1909.5 grams over 17.4 days. The metabolizable energy (ME) within this feed is 11.93 MJ/kg, the Gross energy (GE) is 15.67 MJ/kg, the crude protein (CP) of the diet is 27.66%, and the digestibility (DE) of this feed is approximately 75.75%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the turkey industry[3].

Table4.6 Phase 2 turkey feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-60	46.8
Soya meal	0-36	32.3
Meat & Bone meal	0-12	11.0
Oils/Fats	0-4	2.1
Vitamins/minerals and enzymes	0-2	1.7
Barley	0-18	1.4

Oats	0-12	1.0
Grass seed Fibre	0-10	0.8
Peas	0-10	0.7
Fishmeal	0-5	0.7
Broll	0-5	0.7
Amino Acids	0-0.7	0.5
Blood meal	0-2	0.1
Limestone	0-0.8	0.1
Dicalcium Phosphate	0-0.5	0.1

Phase 3:

Turkeys in the third phase of feeding are fed 3788.1 grams over 21.3 days. The metabolizable energy (ME) within this feed is 11.86 MJ/kg, the Gross energy (GE) is 15.41 MJ/kg, the crude protein (CP) of the diet is 25.24%, and the digestibility (DE) of this feed is approximately 76.55%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the turkey industry[3].

Table4.7 Phase 3 turkey feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-70	59.7
Soya meal	0-30	29.0
Meat & Bone meal	0-10	3.5
Barley	0-19	1.8
Vitamins/minerals and enzymes	0-1.7	1.6
Oats	0-13	1.2
Oils/Fats	0-3	1.1
Grass seed Fibre	0-10	1.0
Amino Acids	0-.6	0.5
Limestone	0-2	0.3
Peas	0-9	0.1
Blood meal	0-2	0.1
Dicalcium Phosphate	0-1	0.1

Phase 4:

Turkeys in the fourth phase of feeding are fed 3584.4 grams over 14.1 days. The metabolizable energy (ME) within this feed is 11.87 MJ/kg, the Gross energy (GE) is 15.26 MJ/kg, the crude protein (CP) of the diet is 20.63%, and the digestibility (DE) of this feed is approximately 77.77%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the turkey industry[3].

Table4.8 Phase 4 turkey feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-70	64.2
Soya meal	0-25	14.1
Meat & Bone meal	0-11	9.7
Broll	0-7	5.1
Barley	0-20	1.8

Vitamin/minerals and enzymes	0-2	1
Oats	0-10	0.9
Oils/Fats	0-3	0.9
Grass seed Fibre	0-10	0.8
Amino Acids	0-0.5	0.4
Peas	0-3	0.3
Dicalcium Phosphate	0-1	0.1
Blood meal	0-1	0.1

4.7 Duck placement and processing statistics

The only duck breed utilized in New Zealand for meat production is the Peking duck.

Approximately 810,800 birds in the 2009-2010 financial year were placed in production systems across the entire duck industry. This accounted for a total of 786,000 birds being processed for duck meat which were all from barn production systems.

Production system mortality for the total industry was (3.06% ± 0.013), as determined by a weighted average across the entire industry[3].

The average number of days required to grow a duck required approximately 45 days and the average number of birds that were grown within this financial year totaled 99,962 birds (this figure is equivalent to the number of ducks it would take if they were grown for a full year – form more information on this figure see section 7).

4.8 Duck litter management

100% of the bedding material consists of wood shavings. It has been estimated that approximately 2,500 tonnes of bedding material is utilized in the duck industry. Approximately 7,100 tonnes of used litter is produced from these production systems.

The duck industry generally removes litter from their operations 6 times a annum/shed (weighted average)[1]. The used litter that is collected is sold as a fertilizer material (100%), which is spread on land.

It is practice for used litter collection companies to generally spread used litter or fertilizer on land almost immediately after collection. However, in the situations when it is raining, wet or if the demand for the used litter is not there, then used litter is generally collected and dry stored until it can be used. We also note that the use of poultry manure is driven by the cost of oil (where if the cost of oil becomes more affordable to make synthetic fertilizers, this means the demand for used poultry litter will decrease, and vice-versa).

4.9 Information on duck feed

The duck industry is utilizes 2 feeding phases. The following feed information is based upon a weighted average[3] of these feeding phases. Please note that the ingredients used in manufacturing duck feed will primarily depend on the availability and cost of the feed ingredients. Furthermore, each feed is generally manufactured to ensure that ducks are receiving the necessary components of a diet to promote growth and/or performance.

Phase 1:

Ducks in the first phase of feeding are fed 625.66 grams over 10.2 days. The metabolisable energy (ME) within this feed is 12.57 MJ/kg, the Gross energy (GE) is 16.88 MJ/kg, the crude protein (CP) of the diet is 22.00%, and the digestibility (DE) of this feed is approximately 74.27%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the duck industry[3].

Table 4.9 Phase 1 duck feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-70	53.1
Soya meal	0-23	22.6
Maize	0-11	10.4
Meat & Bone meal	0-10	6.3
Oils/Fats	0-2.3	2.2
Blood meal	0-3	1.7
Wheat Bran	0-1.3	1.2
Barley	0-20	0.9
Vitamins/minerals and enzymes	0-1.3	
Limestone	0-0.5	0.5
Amino Acids	0-0.5	0.2

Phase 2:

Ducks in the second phase of feeding are fed 4752.94 grams over 34.8 days. The metabolisable energy (ME) within this feed is 12.86 MJ/kg, the Gross energy (GE) is 16.86 MJ/kg, the crude protein (CP) of the diet is 18.74%, and the digestibility (DE) of this feed is approximately 76.18%. The following table provides the range of feed ingredients (in percent) as well as a 'hypothetical' diet (in percent) based off of the data provided by the duck industry[3].

Table 4.10 Phase 2 duck feed data

Raw Materials:	Range (%):	'hypothetical' diet (%):
Wheat	0-70	63.4
Soya meal	0-14.8	14.5
Meat & Bone meal	0-10	6.3
Oils/Fats	0-2	1.9
Blood meal	0-1.3	1.2
Vitamins/minerals and enzymes	0-0.6	0.8
Barley	0-20	0.9
Limestone	0-0.6	0.5
Amino Acids	0-0.5	0.1

4.10 Layer hen flock statistics

The most common layer breed utilized in New Zealand for egg production is the Shaver bird. Approximately 62.4% of the birds housed for egg production are this breed. The remaining 37.6% of birds are the Hyline breed.

A total of 2,122,062 hens (i.e. 86.3%) counted in the survey were from caged production systems, 70,520 hens (i.e. 2.9%) were from enriched colony cages, 124,500 (i.e. 5.1%) were from barn production systems and 141,830 (i.e. 5.8%) were from free range production systems.

These bird numbers included survey from 26 cage production systems, 3 enriched colony cage production systems, 4 barn production systems and 24 free range production systems. The proportion of shaver layer hens that were housed in cage production systems were 61.4%, 67.4% in enriched colony cages, 66.5% in barn and 72.0% in free range production systems.

Industry average mortality was determined to be 3.5 ± 1.8%. The overall industry mortality figure was approximately 3.19% (weighted average)[3]. Production system specific mortality was determined to be 3.3% for cage systems, 3.1% for enriched colony cage systems, 4.1% for barn systems and 7.0% for free range systems.

The average number of weeks hens were in lay for the entire industry was 61 weeks[3]. Hens from both cage and enriched colony cage production systems had an average laying period of 61 weeks, whereas hens in barn production systems had an average laying period of 55 weeks and hens in free range production systems had an average laying period of 64 weeks.

The average age that hens are placed into egg production systems across the entire industry was 18 weeks[3]. Hens from both cage production systems had an average placement of 18 weeks, whereas hens in enriched colony cage production systems had an average placement of 16 weeks. Hens in both barn and free range production systems had an average placement of 17 weeks.

4.11 Layer hen litter management

Approximately 97.8% (approximately 9 tonnes) of bedding material used in barn production systems consists of wood shavings. The remaining tonnage of bedding material (i.e. 0.2 tonnes) consists of bark. Approximately 52.8% (approximately 15.4 tonnes) of bedding material used in free range production systems consists of wood shavings. The remaining tonnage of bedding material (i.e. 13.8 tonnes) consists of bark (i.e. 9.8 tonnes or 33% of the total tonnage of bedding material), straw (i.e. 2.5 tonnes or 8.4% of the total tonnage of bedding material), sawdust (i.e. 1.4 tonnes or 4.7% of the total tonnage of bedding material) and seed pods (i.e. approximately 0.1 tonnes or 0.7% of the total tonnage of bedding material). Bedding material for both cage and enriched colony cage production systems is not used.

Approximately 22, 376 tonnes of used litter is produced from the total layer industry. This consists of 18,416 tonnes (i.e. 82.3%) from cage systems, 95 tonnes (i.e. 0.4%) from enriched colony cage systems, 1,135 tonnes (i.e. 5.1%) from barn systems and 2,731 tonnes (i.e. 12.2%) from free range production systems.

The layer industry generally removes manure/litter from their operations 55 times per annum (weighted average)[3]. This frequency is slightly greater than weekly removal from egg production systems. Cage production systems have manure removed from their sheds approximately 61 times per year. Enriched cage production systems have manure removed from their shed approximately 52 times per year. Barn production systems have litter removed from their sheds approximately 20 times per year (i.e. between every two to three weeks) and free range production systems have litter removed from their sheds approximately 5 times per year (i.e. between every two to three months).

Overall 97% (i.e. 21,733 tons) of manure and used litter collected from the industry is used as fertilizer and spread on general farming land, pasture, or dairy pasture and 2% (i.e. 421 tonnes) of manure is stored before it is spread or applied to land. Approximately 1% (i.e. 120tonnes) of used litter/manure is stored in a pit and mixed with water before being combined with cattle manure (i.e. to produce a liquid slurry mixture) and applied to farm land. 102 tonnes of used litter is also further composted, but this amount is negligible (i.e. less than 1%) compared to the other overall industry methods of managing manure/used litter. Both cage and colony cage production systems reported that all of their waste litter is used as fertilizer and spread on general farming land, pasture, dairy pasture or stored before it is spread or applied to land. Barn and free range production systems also spread their waste litter (94% and 95%, respectively). Additionally, the barn and free range production systems did report that they compost litter (6% and 2%, respectively). Additionally,one free range farm also reported that they utilize a pit storage system (3%).

It is practice for used litter collection companies to generally spread used litter or fertilizer on land almost immediately after collection. However, in the situations when it is raining, wet or if the demand for the used litter is not there, then it is generally collected and dry stored until it can be used. We also note that the use of poultry manure is driven by the cost of oil (where if the cost of oil becomes more affordable to make synthetic fertilizers, this means the demand for used poultry litter will decrease, and vice-versa). Additionally, manure produced by cage and enriched colony cage production systems is often dried down prior to removal from layer sheds.

4.12 Layer hen feed information

The average number of feeding phases that the layer industry uses is 3. For each specific production system, the numbers of feeding phases consist of 3, 2, 2 and 3 phases for cage, barn, free range and enriched colony cage systems, respectively. This data is based upon a weighted average[3].

On average, the metabolisable energy of layer feed consists of 11.7 MJ/kg, a crude protein percentage of 17.3%, a digestibility percentage of 76.3 and a gross energy of 15.3 MJ/kg. Cage production systems contain layer diets that consist of 11.7 MJ/kg, a crude protein percentage of 17.2%, a digestibility percentage of 76.5 and a gross energy of 15.3 MJ/kg. Barn production systems contain layer diets that consist of 11.7 MJ/kg, a crude protein percentage of 17.8%, a digestibility percentage of 75.5 and a gross energy of 15.5 MJ/kg. Free range production systems contain layer diets that consist of 11.8 MJ/kg, a crude protein percentage of 17.9%, a digestibility percentage of 75.2 and a gross energy of 15.7 MJ/kg.

Enriched colony cage production systems contain layer diets that consist of 11.7 MJ/kg, a crude protein percentage of 17.2%, a digestibility percentage of 76.5 and a gross energy of 15.3 MJ/kg.

Cage hens are feed an average of 102 grams of feed/day within their first feeding phase, 104 grams of feed/day within their second feeding phase and 107 grams of feed/day during their third feeding phase. Overall, this equates to an average of 105 grams of feed/day during all three phases. Barn hens are feed an average of 120 grams of feed/day within their first feeding phase and 124 grams of feed/day during their second feeding phase. This equates to an average of 122 grams of feed/day during all two phases. Free range hens are feed an average of 123 grams of feed/day within their first feeding phase and 127 grams of feed/day during their second feeding phase. This equates to an average of 125 grams of feed/day during all two phases. Enriched colony caged hens are feed an average of 102 grams of feed/day within their first feeding phase, 105 grams of feed/day within their second feeding phase and 107 grams of feed/day during their third feeding phase. Overall, this equates to an average of 106 grams of feed/day during all three phases. Industry averages are equivalent to 104 grams of feed/day during phase 1, 106 grams of feed/day during phase 2, 107 grams of feed/day during phase 3 and a total industry average of 107 grams of feed/day during all three feeding phases.

Phase 1 for caged hens generally lasts 4 weeks, phase 2 lasts 28 weeks and phase 3 lasts 29 weeks. Phase 1 for Barn hens lasts 27 weeks and phase 2 lasts 28 weeks. Phases 1 and 2 for free range hens last 32 weeks each. The industry average weeks/phase consist of 7, 28 and 29 weeks for phase 1, phase 2 and phase 3, respectively.

The feed ingredients used in manufacturing layer feed will primarily depend on the availability and cost of the ingredients. Furthermore, each feed is generally manufactured to ensure that the hens are receiving the necessary components of a diet to promote growth and performance (i.e. egg production). The following feed data provide a list of the general feed ingredients utilized for each different production system as well as a ‘hypothetical’ diet (in percent) based off of the data provided by the layer industry[3].

Table 4.11 Feed data for caged production systems

Raw Materials:	Range (%):	Weighted & norm average:
Wheat	0-55	50
Soya meal	0-20	9
Maize	0-75	10
Meat & Bone meal	0-10	5
Sorghum	0-20	2
Oils/Fats	0-6	3
Vitamins/minerals and enzymes	0-20	8
Broll	0-15	4
Amino Acids	0-3	2
Barley	0-25	6
Sunflower Meal	0-15	0
Canola Meal	0-3	0

Blood Meal	0-10	1

Table 4.12 Feed data for barn production systems

Raw Materials:	Range (%):	Weighted & norm average:
Wheat	0-55	45
Soya meal	0-20	9
Maize	0-75	10
Meat & Bone meal	0-10	7
Sorghum	0-20	2
Oils/Fats	0-6	3
Vitamins/minerals and enzymes	0-20	8
Broll	0-15	6
Amino Acids	0-3	2
Barley	0-25	7
Sunflower Meal	0-15	0
Canola Meal	0-3	0
Blood Meal	0-10	1

Table 4.13 Feed data for free range production systems

Raw Materials:	Range (%):	Weighted & norm average:
Wheat	0-65	50
Soya meal	0-20	6
Maize	0-60	4
Meat & Bone meal	0-10	5
Sorghum	0-20	0
Oils/Fats	0-6	3
Vitamins/minerals and enzymes	0-20	10
Broll	0-15	4
Amino Acids	0-3	2
Barley	0-20	15
Sunflower Meal	0-15	0
Canola Meal	0-3	0
Blood Meal	0-2	1

Table 4.14 Feed data for enriched colony caged production systems

Raw Materials:	Range (%):	Weighted & norm average:
Wheat	0-55	50
Soya meal	0-20	9
Maize	0-75	6
Meat & Bone meal	0-10	5
Sorghum	0-20	2
Oils/Fats	0-6	3
Vitamins/minerals and enzymes	0-20	10
Broll	0-15	5
Amino Acids	0-3	2
Barley	0-20	9
Sunflower Meal	0-15	0
Canola Meal	0-3	0
Blood Meal	0-2	1

4.13 Summaryof waste management systems used in the commercial poultry industry

The following table summarizes the waste management systems in use in the meat chicken, turkey, duck and layer industries within New Zealand:

Table 4.15 Summary of management systems and manure management systems

Poultry Species	Management System (MS)	Manure Managed	Methane Conversion Factor (MCF)
Meat chicken	95.1% barn	stored/spread	1.5%
	4.9% free range	stored/spread	1.5%
Turkey	89.4% barn	stored/spread	1.5%
	10.6% free range	stored/spread	1.5%
Duck	100% barn	stored/spread	1.5%
Layer hen	86.3% cage	stored/spread	1.5%
	5.1% barn	94% stored/spread	1.5%
		6% composted	1%
	5.8% free range	95% stored/spread	1.5%
		2% composted	1%
		3% pit stored	35%*
	2.9% colony cage	stored/spread	1.5%

** value taken from IPCC 1996Guidelines (IPCC, 1996).*

5 EMISSION FACTORS AND THEIR UNCERTAINTIES

Table 5.1 contains a summary of the key emission factors and the range of values reported in the literature. Where New Zealand specifc values are available these have been used by preference, even though in some instances (e.g., EF_3) these values are not poultry-specific. Emission factors have been disaggregated by poultry type and system where possible.

Many studies did not include any uncertainty estimates so it is difficult to assess the relative reliability of the different studies. Likewise, it is not simple to determine which studies were closest to New Zealand conditions. For these reasons we have taken a cautious approach and quote the median and range for each factor. The median has the advantage that it is less susceptible to being affected by extreme results than the mean, while the range gives the maximum deviation. Table 5.22 also includes the % uncertainty, i.e. the difference between the extremes of the range and the median as a percentage of the median.

Emissions calculations usually involve multiplying activity data by the appropriate emission factor. When factors are multiplied the uncertainty in the product is given by:

$$U_{TOT} = (U_1^2 + U_2^2 + \ldots + U_n^2)^{0.5} \qquad \text{(Equation 12, IPCC 2006)}$$

where U_{TOT}, and U_i represent percentage uncertainties.[4]

Emission factors with a high percentage uncertainty will lead to high percentage uncertainties in the corresponding calculated emission.[5] Looking at Table 5.22 we can identify N_2O emissions from animal manure in management systems (EF_3) and applied to soils (EF_1), and NH_3 from poultry housing as factors with high percentage uncertainties. For EF_3 and NH_3 from poultry housing the emission factors are based on international values, so obtaining New Zealand-specific data could reduce the uncertainty in the inventory. EF_1 is New Zealand specific, but based on urea fertiliser rather than poultry manure.

Note that in this assessment we have considered the magnitude of the % uncertainty. The appropriateness of these emission factors to New Zealand poultry conditions is discussed elsewhere.

[4] Note that the IPCC calculates the percentage uncertainties based on the 95% confidence interval, while we have used total range.

[5] Although, if the source is relatively small,this may not be important to the total inventory.

Table 5.1 Summary of key factors based on review of literature

Factor	Definition	Animal type	System	Median	Range	% uncertainty	Comments	References
B_0	Maximum CH_4 production capacity for manure ($m^3 CH_4$ kg^{-1} VS)	Layers Meat chickens Turkey Ducks		0.39 0.375 0.36 0.36	0.332 - 0.496 0.306 - 0.414 ± 15% ± 15%	-15 - +27% -18 - +10% ± 15% ± 15%		IPCC (2006), Woodbury and Hashimoto (1993), Yang and Change (1978), Webb and Hawkes (1985), Field et al (1985)
EF_3	N_2O emission factor for organic N application to soil	Not poultry specific		0.01*	0.0003 - 0.027	-97% - +170%	NZ specific, based on urea	Kelliher and de Klein (2006)
EF_3	N_2O emission factor for animal manure in management systems	Poultry specific Not poultry specific	Poultry manure with litter Poultry manure with out litter Solid storage Compost - in vessel Compost - static pile Compost - intensive windrow Compost - passive windrow	0.001 0.001 0.005 0.006 0.006 0.1 0.01		-50 - +100% -50 - +100% -50 - +100% -50 - +100% -50 - +100% -50 - +100% -50 - +100%	Default values	IPCC 1996, 2006
$FRAC_{gasm}$	Fraction of total animal manure emitted as NO_x or NH_3	Not poultry specific		0.1*	0.048 - 0.138	-52 - +38%	NZ specific value	Sherlock et al 2009
$FRAC_{Leach}$	Fraction of N input to soils that is lost through leaching and runoff	Not poultry specific		0.07*	0.03 - 0.10	-57 - +43%	NZ specific value	Thomas *et al.* 2005
$FRAC_{LossMS}$	Total N loss from animal waste management system during housing, treatment and storage	Poultry	Poultry without litter Anaerobic lagoon Poultry with litter	55% 40% 40%	40-70% 25-75% 10-60%	± 27% -37.5 - +87.5% -75 - +50%	Default values	IPCC 2006

Factor	Definition	Animal type	System	Median	Range	% uncertainty	Comments	References
MCF	CH_4 conversion factor		Solid storage					IPCC 1996, 2006
			cool	0.01		±20%		
			temperate	0.015		±20%		
			Compost - in vessel	0.005		±20%		
			Compost - static pile	0.005		±20%		
			Compost - intensive windrow					
			cool	0.005		±20%		
			temperate	0.01		±20%		
			Compost - passive windrow					
			cool	0.005		±20%		
			temperate	0.01		±20%		
N_{ex}	N excreted kg animal^{-1} y^{-1}	Layers		0.416	0.32 - 0.511	± 23 %	NZ data	ASAE (2005), NZAEI (1985), PIANZ and EPFNZ (2010), MAF (1986) and Mahimairaja et al. (1993), Smith et al. (1999)
		Meat chickens		0.39	NA			
		Turkeys		3.0	NA			
		Ducks		0.74	0.58 - 0.90	± 22 %	International data	
NH_3 housing	NH_3 losses from poultry housing (g d^{-1}animal^{-1})	Meat chicken	Litter floor	178	0 - 768	-100 - +330%		Amon et al. (1997), Asman (1992), Demmers *et al.*(1999), Gates *et al.* (2007), Gay *et al.*(2005), Groot Koerkamp et al. (1998), Hartung and Phillips (1994), Heber *et al.* (2005), Hyde et al. (2003), Jacobson *et al*. (2004), Lacey et al. (2003), Misselbrook et al. (2000), Nicholson et al. (2004), Oldenburg et al. (1992), Phillips et al. (1995), Sneath *et al*. (1996), Van Der Hoek (1998, 2005), Wathes *et al.* (1997), Wheeler et al. (2006)
		Layer	Battery cage	120	15 - 295	-88 - +146%		
			Deep pit	219	33.6 - 261	-85 - +19%		
			Perchery	218	177 - 261	-19 - +20%		
			3-tier cage	64.8	NA			
			High Rise	350	200 - 724	-43 - +107%		
		Turkey	Not specified	117	7.2 - 126	-94 - +8%		
VS	volatile solids excreted (kg animal^{-1}d^{-1})	Layers		0.014	0.009 - 0.019	± 36%	NZ data	ASAE (2005), NZAEI (1985), IPCC(2006), PIANZ and EPFNZ (2010), MAF (1986 and Mahimairaja et al. (1993)
		Meat chickens		0.019	0.015 - 0.0233	± 22%		
		Turkeys		0.11	NA			
		Ducks		0.023	0.020 - 0.0256	± 12%	International data	

*Represents New Zealand specific default values for inventory rather than median value

6 EMISSION CONCLUSIONS AND RECOMMENDATIONS

The National Inventory Report (NIR) on greenhouse gas (GHG) emissions for the New Zealand poultry industry has currently been assigned default Tier I international standards provided by the Intergovernmental Panel on Climate Change (IPCC) for most of the calculations used to determine its GHG emissions profile. This review of available international and NZ literature was conducted to improve the assumptions for poultry emissions estimates, and to replace currently used default values by country-specific information. The review found only limited New Zealand-specific research on GHG emissions from poultry. However, from the review of international and New Zealand literature discussed in sections 3 and 5 it is concluded that

1. the use of IPCC (1996) default values in calculations for methane (CH_4) emissions in the Manure Management section of the National Inventory Report (NIR) results in higher emissions recorded from the poultry industry.

2. the current IPCC (1996) default volatile solids (VS) value (0.10 kg VS day^{-1}) applied to the NZ poultry calculations is an overestimation. The NZ specific VS values estimated for layers and meat chickens are 0.014 and 0.019 kg VS day^{-1}, respectively.

3. the current nitrogen excretion (Nex) default value of 0.6 kg N animal^{-1} year^{-1} may overestimate N excretion rates for NZ layer and meat chickens. However, the values reported in the international literature vary widely. Given that layers and meat chickens represent approximately 99% of the poultry animal population a Nex value used in NIR should be representative of the NZ poultry industry.

4. to calculate both CH_4 and nitrous oxide (N_2O) emissions from the poultry industry the division of the population into subclasses (i.e. meat chicken, layer, duck and turkey) and the use of the proposed IPCC 2006 default values would improve the accuracy of the VS and Nex parameters.

5. the review of literature identified the lack of NZ and international data to provide details on a Methane Conversion Factor (MCF), and direct N_2O emissions from land-applied poultry manure (EF_3) factors for the poultry industry within NZ.

6. it is currently unclear how MCF and EF_3 values during composting of poultry manure should be included into inventory calculations. It is recommended that clarification on the application of these values are sought from the IPCC.

7. in the absence of appropriate studies, proposed IPCC 2006 guidelines, which provide specific categories for the poultry industry and default values, seem the most reliable source for EF_3 that would increase the confidence of the poultry industry in the values being applied in the NIR.

8. the use of the 'Other' MS category in the current inventory calculation for manure management may overestimate N_2O emissions when compared with using the proposed IPCC 2006 guidelines, where EF_3 for litter category birds are reduced from 0.005 to 0.001 kg N_2O-N/kg N. To reduce uncertainty in this calculation further research needs to be undertaken to develop MS factors by subclass (meat chicken, layer (wet and dry), duck, turkey).

9. N volatalisation loss from AWMS can be significant for poultry manure. It is estimated that N loss can range between 40 and 55% of total N excreted. The current calculations in the NIR do not take into account the N losses and result in a higher than actual N application to agricultural soils. The IPCC (2006) addresses these concerns in their proposed methodology by introducing a $Frac_{LossMS}$ emission factor that should be included in NIR.

10. N_2O emissions from poultry manure can vary depending upon the composition of the manure (fresh, composted, wet or dry), and the environmental conditions in which the manure is applied (temperature, moisture content). New Zealand has developed a country-specific EF_3 of 0.01 for emissions from animal excreta deposited in grazed pastures, which is similar to that calculated from international literature.

11. NZ has recently developed an indirect factor for ammonia emissions from animal manure of 0.1 (kg NH_3-N + NOx-N/kg of N excreted by livestock) of N deposited. The international data indicate that this may underestimate ammonia emissions from poultry manure.

12. NZ has developed a country-specific value for $Frac_{LEACH}$ that takes into consideration NZ environmental and agricultural management parameters. For leaching from poultry manure some variation may be expected, based on the composition of the manure and application method when compared with the parameters used to develop the $Frac_{LEACH}$. Further work is required if a more accurate industry specific value is to be developed.

13. limited literature is available on EF_5 values globally. The proposed IPCC 2006 guidelines recommend a reduction in EF_5 from 0.025 to 0.0075 kg N_2O-N/Kg. This reductions takes into account a NZ study EF_5 value based on N_2O emissions from NZ rivers. Thus the IPCC 2006 recommended value may better represent NZ conditions for EF_5 than the existing default value.

14. N_2O emissions from manure management systems and NH_3 from animal housing had very large % uncertainties (and are based on either international or non-poultry specific data). Further research is needed to improve these estimates to reduce uncertainties in the overall poultry inventory.

This review suggests that the use of current IPCC (1996) default values of VS and Nex in the calculations of CH_4 and N_2O emissions from the NZ poultry industry results in overestimates. To improving the accuracy of CH_4 and N_2O emissions from poultry in NZ it is recommended that:

i) the poultry population is divided into subclasses (i.e. meat chicken, layer, duck and turkey) and the EFs of each subclass are used.

ii) the current IPCC default mean VS value of 0.10 kg VS day^{-1} is replaced with the NZ specific VS values of 0.014 kg VS day^{-1} for layers, 0.019 kg VS day^{-1} for meat chickens, 0.023 kg VS day^{-1} for ducks and 0.11 kg VS day^{-1} for turkeys.

iii) the current IPCC mean Nex default value of 0.6 kg N $animal^{-1}$ $year^{-1}$ is replaced with NZ specific values of 0.42 kg N $animal^{-1}$ $year^{-1}$ for layers, 0.39kg N $animal^{-1}$ $year^{-1}$ for meat chickens only. As there is no NZ Nex data for ducks and turkeys the value of 0.60 kg N $animal^{-1}$ $year^{-1}$ be maintained.

iv) the current non-poultry-specific EF_3 0.005 kg N_2O-N/kg for litter category birds is reduced to poultry-specific EF_3 0.001 kg N_2O-N/kg N from AWMS.

v) a conservative value of 40% N volatalisation loss ($Frac_{LossMS}$) from AWMS is included in the NIR to improve the accuracy of N application to agricultural soils.

vi) for manure N application to agricultural soils NZ specific EF_3 of 0.01 for emissions from animal excreta deposited in grazed pastures is used to calculate N_2O emissions and $Frac_{gasm}$ of 0.1 and $Frac_{leach}$ of 0.07 are used to calculate gaseous and leaching losses from poultry manure applied to agricultural soils.

7ANNUAL AVERAGE POPULATIONS OF POULTRY HOUSED IN COMMERCIAL PRODUCTION SYSTEMS IN NEW ZEALAND

The following sections will explain how the flock sizes within the poultry industry in New Zealand are determined. This section will also discuss proposed alternatives to better determine some of these annual average flock sizes.

7.1 Poultry meat production

Statistics New Zealand currently determines the meat chicken, turkey meat and duck meat industry's annual flock size through a modelling formula which considers the ratio of the total amount of poultry of type (species) '$_i$' processed (plus poultry of type '$_i$' mortality) produced in New Zealand to the number of growing cycles (i.e. rotations) within a calendar year (Chou, pers.com. 2009). Equation 13 illustrates the equation used to estimate the current annual flock size for New Zealand.

$$Annual\ Flock\ Size = \frac{Annual\ Number\ of\ Poultry\, of\ type\, '_i\, '\ Processed}{(1-X_i)*(1-Y_i)*(1-Z_i)*R_i}$$

(Equation 13)

Where:
X_i is the condemned ratio of poultry.
Y_i is the ratio of poultry that are dead on arrival to processing plants.
Z_i is the ratio of the poultry lost while still in sheds during growing.
R_i is the average number of poultry growing cycles (per annum).

Note that ratios X_i, Y_i, and Z_i when added together equal total bird mortality and is equivalent to the difference between the ratio of the total number of birds placed in sheds and the total number of birds processed to the total number of birds placed in sheds. Note that total bird mortality was sought for in the survey of the meat chicken, turkey and duck industries. Thus the denominator in Equation 13 can also be represented by (1 – the total bird mortality) * R_i.

The above equation provides an estimation of how many birds (of a particular poultry species) are on the 30th of June for a given year. However, this equation does not take into consideration the variable amount of downtime between cycles which can vary between 7 to 14 days (Chou, pers.com. 2010; Brooks, pers.com. 2010) as well as the fact that these growing cycles are not synchronized with respect to one another (i.e. potentially contributing to an overestimation in the estimation, itself). Thus, an annual average flock size of the New Zealand meat chicken flock can be more accurately determined by taking the average number of days that meat chickens are alive for ('Days Alive' in Equation 14) multiplied by the ratio of the Annual Number of Poultry of type (species) '$_i$' Processed, i.e. the number of meat chickens processed (including the number of birds that are lost from a combination of mortality and those which are condemned) to the number of days in a calendar year. This approximation would better represent the average annual flock size in New Zealand (see Equation 14) and is also consistent with Equation 10.1 from the 2006 IPCC (International

Panel on Climate Change) Guidelines for National Greenhouse Gas Inventories to determine the annual average population (IPCC, 2006).

$$\text{Average Annual Flock Size} = \frac{\text{Days Alive}}{365} * \frac{Annual\ Number\ of\ Poultry\ of\ type'_i'\ Processed}{(1-X_i)*(1-Y_i)*(1-Z_i)*R_i}$$

(Equation 14)

Where:
'Days Alive' is the average number of days that a species of poultry are grown for.
365 is the number of calendar days in a year.
X_i is the condemned ratio of meat chickens.
Y_i is the ratio of poultry that are dead on arrival to processing plants.
Z_i is the ratio of the poultry lost while still in sheds during growing.
R_i is the average number of poultry growing cycles (per annum).

Note that ratios X_i, Y_i, and Z_i when added together equal total bird mortality and is equivalent to the difference between the ratio of the total number of birds placed in sheds and the total number of birds processed to the total number of birds placed in sheds. Note that total bird mortality was sought for in the survey of the meat chicken, turkey and duck industries. Thus the denominator in Equation 14 can also be represented by 365*(1 – the total bird mortality) * R_i.

In order to determine the number of days that the birds are grown for, i.e. 'Days Alive', a typical growing schedule can identify the day when the poultry birds are removed from the shed for slaughter (PIANZ& EPFNZ, 2010). When at least 50% or half of the entire proportion of birds are removed from a shed, this will correspond to the average number of days that the particular type of poultry is alive for and can be substituted as the variable for 'Days Alive' from Equation 14.
The survey conducted in order to determine poultry management practices in New Zealand sought both poultry processing and placement statistics. Additionally, the number of days birds were alive for and taken from sheds for processing was also compiled across the meat chicken, turkey and duck industries.

Tables7.1-7.3 represent the number of days that correspond to when birds are removed from sheds and taken to slaughter for the entire meat chicken, turkey meat and duck meat industries. These demonstrate that 36 days is appropriate for meat chickens, 68 days is appropriate for turkeys and 45 days is appropriate for ducks.

Table 7.1. Total proportion of meat chickens removed from sheds for slaughter

Days grown	Number of birds	Percentage of birds (%)	Percentage of flock %
28	636,865	0.776%	0.776%
29	636,865	0.776%	1.552%
30	5,555,986	6.769%	8.321%
31	1,529,217	1.863%	10.184%
32	17,688,336	21.551%	31.735%
33	4,343,273	5.292%	37.027%
34	6,145,482	7.487%	44.515%
35	1,899,323	2.314%	46.829%
36	3,896,218	4.747%	51.576%
37	2,951,056	3.595%	55.171%
39	5,721,299	6.971%	62.142%
40	431,933	0.526%	62.668%
41	10,525,930	12.825%	75.493%
42	8,644,868	10.533%	86.025%
43	4,369,192	5.323%	91.349%
45	539,916	0.658%	92.006%
47	6,560,805	7.994%	100.000%

Table 7.2. Total proportion of turkeys removed from sheds for slaughter

Days grown	Number of birds	Percentage of birds (%)	Percentage of flock (%)
56	24,974	9.144%	9.144%
60	37,462	13.716%	22.860%
63	45,786	16.764%	39.624%
68	52,030	19.050%	58.675%
70	47,868	17.526%	76.201%
84	25,000	9.153%	85.354%
91	20,000	7.323%	92.677%
98	10,000	3.661%	96.339%
126	10,000	3.661%	100.000%

Table 7.3. Total proportion of ducks removed from sheds for slaughter

Days grown	Number of birds	Percentage of birds (%)	Percentage of flock (%)
42	375,000	47.710%	47.710%
45	411,000	52.290%	100.000%

Total bird mortality was 3.19% for meat chickens, 5.63% for turkeys and 3.06% for ducks. From Equation 14 the poultry industry in 2009/2010 grew a total of 8,362,330meat chickens, 53,916 turkeys and 99,962 ducks in the calendar year.

7.2 Meat chicken breeding stock

Statistics New Zealand currently determines the meat chicken breeding flock size through an identical modelling equation used to estimate the annual flock size for birds grown for the production of meat. Thus, for the meat chicken breeding stock ($_{bs}$), the following morality ratio estimators and number of rotations for the 2009-2010 calendar year:

X_{bs} is the condemned ratio of breeding stock.
Y_{bs} is the ratio of breeding stock dead on arrival to processing plants.
Z_{bs} is the ratio of the breeding stock lost while still in sheds.
R_{bs} is the average number of breeding stock growing cycles per annum.

The commercial breeding stock in New Zealand predominately remains static throughout a given calendar year to ensure that genetic lines of meat chickens are successfully produced for chicken meat production in New Zealand (i.e. the average number of breeding stock growing cycles is typically equivalent to or slightly less than 1 per year). Thus, the current flock size reported by Statistics New Zealand is representative of the average annual breeding flock size. For the 2009-2010 calendar year, the breeding stock flock size in New Zealand was 564,969 birds (Stats New Zealand, 2011).

7.3 Turkey and duck breeding stock

Stats New Zealand currently determines the breeding flock sizes through surveying farms for the size of their breeding flock (i.e. on June 30th) for a given calendar year (Chou, pers.com. 2010). The breeding flock sizes for both turkeys and ducks are also combined into the 'other poultry' category that is reported by Statisitcs New Zealand. The commercial non-chicken breeding stock in New Zealand remains static throughout an entire calendar year to ensure that genetic lines of turkey and ducks are successfully produced for meat production. Based off of Industry data (PIANZ 2010), the 2009-2010 breeding flock size for turkeys and ducks was approximately 3,020 and 5,150 birds, respectively.
Combining the breeding and meat flock sizes together for both turkeys and ducks gives a total turkey flock size of 56,936 birds and a total duck flock size of 105,112 birds for the 2009-2010 calendar year.

7.4 Hens for commercial egg production

The New Zealand layer hen industry's annual flock size is currently determined through the survey performed by Statistics New Zealand. The total surveyed flock size is determined to be equivalent to the annual average layer hen population (Chou, pers.com. 2010). Because these birds are typically placed in production systems at 18 weeks and remain for 61 weeks (i.e. greater than a calendar year), this flock size is much more static than it is for poultry meat birds grown in New Zealand. When laying hens reach the end of their commercial laying life, a new flock of layer hens will enter the commercial layer flock for egg production, thus ensuring a consistent or steady number of hens in egg production. Therefore the proposed average annual flock size for layer hens will also be equivalent to the annual number of layer hens in production. However, the national average number of hens in production systems in a given year will include farms that house 25 or more birds and farms that are operating without a risk management programme (RMP) and hence are not picked up by New Zealand Food Safety Authority or EPFNZ. It is important to note that the layer industry represented by EPFNZ accounts for commercial operations that purchase more than

99 birds from hatcheries in a given calendar year. Thus the current information provided by Statistics New Zealand will also cover a proportion of the backyard and semi-commercial layer sectors in New Zealand.According to EPFNZ statistics for 2009-2010, the number of hens in lay for egg production was 3,350,290 birds (Stats New Zealand, 2011). However, the adjusted flock size for the purposes of the layer survey was assumed to be 3,015,261 birds for the 2009-2010 year (i.e. equivalent to 90% of the figure published by Stats New Zealand). For purposes of determining GHG emissions in this report, the national flock size reported by Stats New Zealand will be used.

7.5 Replacement stock (pullets) intended for egg production

As with the hens used for egg production (see Section 7.5), the flock size of the pullets intended for egg production are determined by Statistics New Zealand. Statistics New Zealand accomplishes this through the same surveying as previously mentioned. These birds are reared (i.e. grown) for approximately 18 weeks before they are placed in commercial egg producing flocks. Pullet flocks are static as new chicks are constantly becoming reared for egg production. This is to ensure a continuous and steady supply of layer hen stocks available for the production of eggs. Therefore the proposed average annual flock size for reared pullets will also be equivalent to the annual number of pullets reared for the production of eggs. According to Statistics New Zealand for the 2009-2010 calendar year, a total of 1,104828 birds were reared for egg production (Stats New Zealand, 2011).

7.6 Determination of cumulative nitrogen excretion from meat chickens in relation to the average number of days alive

Confirmation whether the average number of days alive is an accurate representation of the cumulative amount of nitrogen emissions being excreted from meat chickens was investigated. Nitrogen excretion values from meat chickens were based off of the recommendations in Section 6 of this report. The daily cumulative nitrogen levels excreted from the total meat chicken population from the first slaughtering date until the last slaughtering date was plotted and a polynomial regressionline was used as this most accurately represent the trend of the plotted data (R^2 =1.00; Figure 2). The polynomial regression equation was then used in order to calculate the cumulative amount of nitrogen being excreted at day 36 for meat chickens. The cumulative amount of nitrogen being excreted from meat chickens on day 36 was determined to be 579,855.0 kg N. The total cumulative amount of nitrogen being excreted from meat chickens was 738,972.6 kg N. Approximately 79% of nitrogen emissions were excreted from meat chickens by day 36.

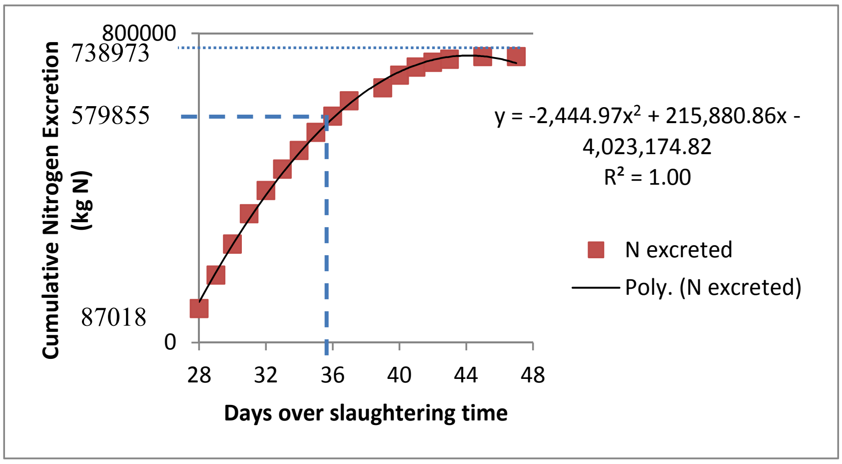

Figure 2 Cumulative nitrogen excretion over slaughter time for meat chickens. The bold dotted lines delineate the amount of cumulative emissions generated at 36 days. The smaller dotted line illustrates the total amount of nitrogen excretted.

8 EMISSION CALULATIONS FROM THE COMMERCIAL MEAT CHICKEN, TURKEY, DUCK AND LAYER HEN INDUSTRIES

The following section will provide an estimation of methane and nitrous oxide emissions from the commercial chicken, turkey, duck and layer hen industries. The population statistics that are used are based of off Section 7 of this report. This section will also provide an estimation of the emission factor assigned to each of these species within New Zealand's Emissions Trading Scheme. Expert opinion from industry personnel is included to provide an indication of how poultry practices have changed in these industries since the 1990's.

8.1 Methane calculations

Methane emissions (based off the recommended VS and methane excretion factors from Chapter 4) from meat chickens, turkey, ducks and layer hens housed in commercial production systems for the 2009-2010 year are 218,560, 7,832, 3,036 and68,511kg CH_4 per year, respectively. Methane emissions from the breeding stocks of meat chickens, turkey, ducks and layer hens for the 2009-2010 year are 20,184, 457, 163 and 17,583kg CH_4 per year, respectively. The total amount of methane emissions from these sectors is238,745, 8,289, 3,199 and 89,788 kg CH_4 per year, respectively.

Assuming that one kg of methane emissions is the equivalent of 21 kg of CO_2 emissions (MAF, 2010), both the commercial meat chicken and layer industries produced a net equivalent of 5,014tonnes of CO_2 and 1,886tonnes of CO_2, respectivellybased on the 2009-2010survey data. The net equivalent for the turkey and duck industries is 174tonnes of CO_2 and 67tonnes of CO2, respectivelybased on the 2009-2010survey data.

8.2 Nitrogen calculations

Nitrogen oxide emissions from meat chickens, turkey, ducks and layer hens housed in commercial production systems for the 2009-2010 year are 4,874, 45, 94 and2,085kg N_2O per year, respectively. Nitrous oxide emissions from the breeding stocks of meat chickens, turkey, ducks and layer hens for the 2009-2010 year are 473, 3, 5 and 603kg N_2O-N per year, respectively. The total amount of nitrous oxide emissions from these sectors is 5,220, 48, 99 and 2,814kg N_2O per year, respectively.

8.3 Direct emissions- animal wastes applied to soils

Direct emissions from meat chickens, turkey, ducks and layer hens housed in commercial production systems for the 2009-2010 year are 43,864, 409, 848 and18,766kg N_2O per year, respectively. Direct emissions from the breeding stocks of meat chickens, turkey, ducks and layer hens for the 2009-2010 year are 3,116, 26, 44 and 6,563kg N_2O per year, respectively. The total amount of direct emissions from these sectors is 46,490, 435, 892 and 25,329kg N_2O per year, respectively.

8.4 Direct emissions- animal production wastes

Directemissions from meat chickens, turkey and layer hens housed in commercial production systems for the 2009-2010 year is2,511, 54and1,282kg N_2O per year, respectively. There are no free range breeding systems.

8.5 Indirect N_2O emissions- volatising of nitrogen

Indirect nitrogen emissions due to volatizing of nitrogen for meat chickens, turkey, ducks and layer hens housed in commercial production systems for the 2009-2010 year are 5,125, 51, 94 and2,211kg N_2O per year, respectively. Indirect nitrogen emissions due to volatizing of nitrogenfor the breeding stocks of meat chickens, turkey, ducks and layer hens for the 2009-2010 year are 346, 3, 5 and 729kg N_2O per year, respectively. The total amount of indirect nitrogen emissions due to volatizing of nitrogen for these sectors is 5,471, 54, 99 and 2,940 kg N_2O per year, respectively.

8.6 Indirect N_2O emissions - leaching of nitrogen

Indirect nitrogen emissions due to the leaching of nitrogen for meat chickens, turkey, ducks and layer hens housed in commercial production systems for the 2009-2010 year are 2,691, 27, 49 and 1,161kg N_2O per year, respectively. Indirect nitrogen emissions due to the leaching of nitrogen from the breeding stocks of meat chickens, turkey, ducks and layer hens for the 2009-2010 year are 182, 1, 3 and 383kg N_2O per year, respectively. The total amount of indirect nitrogen emissions due to the leaching of nitrogen from these sectors is 2,872, 28, 52 and 1,544 kg N_2O per year, respectively.

8.7 Total nitrous oxide generated emissions

The total amount of nitrous oxide emissions from each type of poultryin a given year can be determined by summing the direct, animal and indirect emissions. Thus based on the current survey data and literature review, the meat chicken, turkey, duck and layer industries produced a total level of nitrous oxide emissions of 59,065, 586, 1,086 and 25,506kg N_2O, respectively. The breeding/pullet flocks generated a total of 6,271, 52, 88 and 13,206kg N_2O, respectively.

Assuming that one kg of nitrous oxide emissions is the equivalent of 310 kg of CO_2 emissions (MAF, 2010) both the commercial meat chicken and layer industries produced a net equivalent of 20,254tonnes of CO_2 and 12,001tonnes of CO_2, respectfully based on the 2009-2010survey data. The net equivalent for the turkey and duck industries is 198tonnes of CO_2 and 364tonnes of CO_2 (respectfully) based on the 2009-2010survey data.

8.8 Net emissionsfrom the poultry meat and layer industries

Combining the CO_2 equivalent emissions for methan and nitorous oxide from the meat chicken, turkey, duck and layer industries amount to a total of 25,154, 372, 431, and 13,886 tonnes of CO_2 equvielnt emissions, respectively.

8.9 A reflection from New Zealand specific industry personel on trends in poultry management

Expert opinion from the commercial chicken meat and layer hen industries have noted that some of the changes associated with the produciton of chicken meat and eggs have been due to the increase in the genetic performance of both meat chickens and layer hens. This means that for meat chickens the feed conversion ratio improved from 2 – 2.5 points per year with and increase in producing meat chickens to slaughter weight by approximately 1 full calendar day (John Foulds, Foulds Consulting, 2011, pers. com). In 1990, a slaughter weight of a meat chicken was approximately 1.7 kg, that took 40-42 calendar days, whereas in 2011, the slaughter weight is generally 2.35 kg and takes a total of 36 calendar days (John Foulds, JFoulds Consulting, 2011, pers. com). The meat chicken industry also moved towards utilizing climate controlled shed designs, thus reducing the need for birds to utilize the consumed feed for heat and other maitenance requirements.

In terms of the increased performance of layer hens, it has been noted that feed consumption continues to decrease, allowing for a substantial decrease in the amount of feed required to produce eggs for consumption. This means that layer hens will have a lower feed to eggs conversion ratio, i.e. from about 2.5 kg of feed/kg eggs in 1994 to 1.75 kg of feed/ kg of eggs in 2008 (Trevor Clarke, Tegel, 2011, pers. com). Mr. Clarke has also noted that in the early 1990's there has a large industry movement (i.e. approximately 90% or more of the industry) into multiteir cages in controlled environment sheds. This change coupled with animal husbandry meant that that feed consumption could be better regulated and through the use of controlling the environment. This means that less of the consumed feed would be utilized be the hens for regulating body heat and other maintenance requirements.

There has also been an improvement in knowledge of manufacturing compound feed, i.e. pellet quality, the utilization of enzymes and the useage of amino acids in manufactured feed for both meat chickens and layer hens. All of the above advances have helped increase the digestability of feed (with decreases in feed wastage) leading to a gain in feed conversion and/or efficiency of producing meat chickens and/or egg production (John Foulds, JFoulds Consulting; Trevor Clarke, Tegel, 2011, pers. com).

Disease control and biosecurity has also improved which has led to better growth and/or performance of meat chickens and layer hens. The control of disease has meant that the growth and maintanence of the birds can carry on normally. NZ is recognized by MAF as being free from IBD, Highly Pathenogenic Avian Influenza and NewCastle Disease – all which a common in other poultry producing countries in the world (John Foulds, JFoulds Consulting; Trevor Clarke, Tegel, 2011, pers. com).

8.10 Trends in New Zealand meat chicken production

Through the use a broiler growth model (Emmons Fisher and Gous broiler model), various production paramteters required to growth meat chickens in 1970, 1990 and 2010 were determinedfor the commercial meat chicken industry in New Zealand. The model simulates the growth of birds taking account of genetic parameters, diet composition and feeding programme, the environment, stocking density and other factors which may affect the outcome of production decisions in practice. Growth, feed intake, body composition and yield, and a variety of production indices are calculated in each simulation. This model can provide a means of forecasting and monitoring meat chicken performance and growth (Peter Chrystal, Tegel, 2011, pers. com; EPG Software). The following table provides a summary of the approximate weight of a meat chicken at 48 days, feed intake, feed conversion ratio (FCR) and nitrogen excretion ($N_{excretion}$).Note that ideal slaughter weight in New Zealand generally occurs when birds reach a live weight of approximately 2.3 kg. Based on the same broiler growth model, this could potentially require 48 days in 1970, 39 days in 1990 and 31 days in 2011.

Table 8.1. Parametersdetermined from broiler growing models.

1970			
weight (kg)	$N_{excretion}$ (kg/bird)	feed intake (gm/day)	FCR
2.317	0.143	87.2	1.807
1990			
weight (kg)	$N_{excretion}$ (kg/bird)	feed intake (gm/day)	FCR
2.834	0.130	96.2	1.624
2011			
weight (kg)	$N_{excretion}$ (kg/bird)	feed intake (gm/day)	FCR
3.698	0.097	106.7	1.383

8.11 New Zealand historical figures for meat chickens

Based on the above parameters, the changes in nitrogen excretion, FCR, and days alive (i.e. the number of days before an appropriate slaughter weight is reached) as a function of time can be determined. By assuming a linear trendwith the above parameters, nitrogen excretion, FCR, and days alive can be back calculated in order to determine these values from 1990 to 2011. This information may be used in order to adjust the nitrogen excretion utilized in New Zealand's GHG inventory and is summarized in table 8.2.

Table 8.2. Numbers of meat chickens from 1990 to 2010.

year	days alive	Nitrogen excretion (kg/bird)	FCR	number of meat chickens processed	estimated total amount of N excreted (tonnes)
1990	39	0.123	1.61	44,275,000	5,466
1991	39	0.122	1.60	44,657,000	5,462
1992	39	0.121	1.59	46,498,000	5,635
1993	38	0.120	1.58	50,725,000	6,089
1994	38	0.119	1.57	51,430,000	6,115
1995	38	0.118	1.56	62,119,000	7,316
1996	37	0.117	1.55	62,310,000	7,268
1997	37	0.115	1.54	59,043,000	6,819
1998	37	0.114	1.53	63,325,000	7,242
1999	36	0.113	1.51	64,501,000	7,303
2000	36	0.112	1.50	65,330,000	7,323
2001	36	0.111	1.49	67,822,000	7,525
2002	35	0.110	1.48	72,801,000	7,995
2003	35	0.109	1.47	79,455,000	8,636
2004	34	0.108	1.46	83,648,000	8,996
2005	34	0.106	1.45	89,651,000	9,540
2006	34	0.105	1.44	86,585,000	9,116
2007	33	0.104	1.43	85,023,000	8,855
2008	33	0.103	1.42	81,007,000	8,344
2009	32	0.102	1.41	78,634,000	8,011
2010	32	0.101	1.40	83,666,000	8,428
2011	31	0.100	1.39	N/A	N/A

Processing data obtained from Stats NZ (Stats NZ, 2011).

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