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## Methodologies for the Norwegian national inventory of GHG emissions

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Helge Bonesmo & Eli Johanne Gjerlaug-Enger
Division of Survey and Statistics

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Helge Bonesmo & Eli Johanne Gjerlaug-Enger

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SAMMENDRAG/SUMMARY:

På oppdrag fra Miljødirektoratet presenteres i denne rapporten metodikk for å beregne dyretall i svineproduksjonen, og metodikk for beregning av enterisk metan for gris. Metodikken som beskrives er laget for å passe inn i det norske nasjonale klimagassregnskapet (NIR), og er dynamisk nok til å reflektere genetisk- og driftsmessig framgang over tid. Datagrunnlaget for den foreslåtte metodikken er Landbruksdirektoratet sitt register over alle leverte slakt, og husdyrkontrollen for svin (Ingris) fra Animalia.

Commissioned by the Norwegian Environment Agency, this report presents methodologies for estimating annual numbers of animals and enteric methane emissions for pigs. The methodologies are designed for the Norwegian national inventory of GHG emissions (NIR) and are dynamic, reflecting the effects of progress in genetics and management of the pork production. The data sources for the proposed methodologies are the register for deliveries of carcasses to Norwegian slaughterhouses available from Statistics Norway, and the Norwegian litter recording system (Ingris) of the Norwegian meat and poultry research centre (Animalia).

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|---|---|
| Hildegunn Norheim | Helge Bonesmo |
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# Preface

Pork can be a valuable source of protein supply in sustainable food production. This is in particular valid for areas with a humid and cold climate with limited possibilities for growing high quality protein crops. Pork production in Norway makes it possible, even under such climatic conditions, to contribute to reduce the pressure on the world's vulnerable natural areas by using local resources. However, to ensure a solid base for the environmental impact of Norwegian pork production it is necessary to have methodology that estimates the number of animals precisely, and methodology for net emissions of greenhouse gasses that are reflecting the composition of the animal population. We expect that the work presented in this report will contribute to achieve a higher accuracy of the estimates of net greenhouse gasses attributed to pork production in the Norwegian National Inventory Report.

Trondheim, 20.10.22

Helge Bonesmo

# Content

# 1. Introduction

The memorandum of understanding between the agricultural sector, represented by the Norwegian Farmers Union and the Norwegian Farmers and Smallholders Union, and the Norwegian government necessitates a reduction of net greenhouse gas (GHG) emissions corresponding to five million metric tons $CO_2$ eqs from the agricultural sector during the period 2021–2030.

Generally, agricultural production systems are complex biological systems that invariably involves trade-offs at farm level when it comes to GHG mitigation options such that the reduction most likely has to be a result of smaller steps (*e.g.* Bonesmo et al., 2013). Thus, to reach the goal of five million tons $CO_2$ eqs reduction, mitigation options must be searched within every production system in the sector. As pork is the preferred meat for consumption in Norway, estimated to 20.2 kg pork per capita and year (Animalia, 2021), measures for GHG reductions from pig production systems will certainly be expected. Of the GHG emissions from pork production, the enteric emissions, and the emissions from manure in buildings and storage and use, are attributed to the agricultural sector in national GHG inventory (Norwegian Environment Agency, 2021). For 2020, the emissions related to manure are estimated to 55014 t $CO_2$ eqs per year from manure in buildings and storage, 24888 t $CO_2$ eqs per year from manure use, and the enteric methane ($CH_4$) emissions are estimated to correspond to 28642 t CO2. These estimated emissions add up to 108544 t $CO_2$ eqs per year and contribute with 2.38 % to the GHG emissions attributed to the agricultural sector (pers. comm. Berit Storbråten, Statistics Norway).

Bonesmo & Enger (2021) demonstrated that the IPCC GHG estimation system (Eggleston et al., 2006) was capable of reflecting the effects of progress in genetics and management on GHG emissions from Norwegian pork production. As National Inventory Reports (NIR) for GHG emissions (*e.g.* Norwegian Environment Agency, 2021) is based on the IPCC GHG estimation system, the effects of progress in pork production should be reflected in the NIR. However, the current methodology for estimation of activity data (*i.e.* animal numbers) for the Norwegian pig production has not been updated since 2012, and is too static to reflect changes in the composition of pig population caused by progress in genetics and management. The current methodology for estimating enteric $CH_4$ emissions from pigs is not capable of reflecting changes in the composition of pig population as it uses the same emissions factors for all categories of pigs. Thus, as required by Norwegian Environmental Agency, the objective of this work was to provide updated and dynamic methodologies for activity data and enteric $CH_4$ emissions for pigs that are capable of reflecting the progress of genetics and management in pork production.

# 2. Data Sources

The proposed methodology for activity data is based on the combination of two reliable, robust, readily available, and complementary data sources: 1. The register for deliveries of carcasses to Norwegian slaughterhouses, which is a comprehensive source for the number of all animals registered for slaughter in Norway; and 2. The Norwegian litter recording system (Ingris). Ingris is a web-based management system for pigs and is the predominantly used registration system for pig management in Norway. By using these two data sources, the use of the farmers reported numbers for governmental payments (PT data) can be avoided. The PT data provides the number of animals at the farm twice a year and may be subject to considerable uncertainty. The estimation of animal numbers throughout the year (animal and year) based on PT data collected twice a year inevitable involves several assumptions regarding the production characteristics.

The first data source, The register for deliveries of carcasses to Norwegian slaughterhouses, is available from Statistics Norway, https://www.ssb.no/en/jord-skog-jakt-og-fiskeri/jordbruk/statistikk/kjotproduksjon . Until 1995, the statistics was based on forms from each slaughterhouse, where the number and weight of carcasses of different categories per month was registered. The location of the holdings with deliveries of carcasses was not registered on the forms, and it was not possible to derive other figures than deliveries per month of the different categories of carcasses. Starting from 1995, the statistics is based on use of register data, and figures can also be provided for approved carcasses by counties and municipalities. As this register encompasses all animals slaughtered in Norway, the source provides the most reliable indicator for the volume of Norwegian pork production. The methodology for assessment of the number of animals in categories of pigs proposed in the current work is based on the number of finishers slaughtered, including immunocastrated boars.

The second data source, Ingris, is published annually by the Norwegian Meat and Poultry research Centre (Animalia), and the last eleven years are available from: https://www.animalia.no/no/Dyr/husdyrkontrollene/ingris/arsstatistikk/. Data for earlier years are available for use in the NIR by contacting Animalia. The purpose of the Ingris is to provide operational decision support for the management of pig producing units. Thus, the Ingris has a high level of detail and are complementary to the comprehensive data from "The register for deliveries of carcasses to Norwegian slaughterhouses". The Ingris does not cover the entire national pig population, in 2021 the participation was about 76% of the sows and gilts, 12% of the weaners and 29% of the finishers (Ingris, 2021). For the proposed methodology for assessment of the number of animals, the Ingris data are divided into the four categories, Sows, Gilts, Weaners, and Finishers, and the number of animals in each category throughout the year is calculated as the sum of the number of days over individual animals in the category divided by 365 days.

It is noteworthy that the first data source, coverage close to 100%, is the base for the calculation of animal numbers in all categories. The second data source is used for estimation of key characteristics of the pig production; equivalent to the use of representative experimental derived variables and parameters used in the NIR.

The suggested approach for estimating dynamic category specific emission factors of enteric $CH_4$ for pigs is based on the equations developed by Philippe and Nicks (2015). In the current work, methodology for deriving input data from Ingris to the estimation of enteric $CH_4$ for the four categories, Sows, Gilts, Weaners, and Finishers, is proposed.

# 3. Results

The developed methodology provides estimates for numbers of animals throughout the year (animal and year) and equations for estimates of enteric methane for four categories of pigs: **(1)** Sows, from the first insemination resulting in a litter and with a live weight (LW) higher than approximately 160 kg; **(2)** Gilts, from approximately 120 to 160 kg LW; **(3)** Weaners, from weaning at approximately 10 kg LW and until they enter the finisher stage at approximately 30 kg LW; **(4)** Finishers, from approximately 30 kg LW to the time of slaughter at approximately 120 kg LW, this category also includes the animals destined for piglet production until entering the Gilts category. For the category Boars, it is not necessary to develop new methodology but continue to use the current one. Due to artificial insemination, the number of boars for breeding has steadily declined, and the national population of boars has the last three years been fewer than 900. The suggested methodology appears in detail in a companion Excel Spreadsheet delivered to the Environmental Agency together with this report. In the subsequent two sections the proposed methodology for estimating animal numbers and the methodology for estimating enteric methane for pig categories are presented with references to the variable names in the companion spread sheet.

## 3.1. Estimating the number of animals for four categories of pigs

The estimation of the numbers of (animal and year) per pig category is based on the total number of finishers recorded as slaughtered (*e.g.* Animalia, 2021), and the calculation of (animal and year) of four categories of pigs is undertaken by deriving relationship between slaughtered finishers and the needed numbers of animals in each of the four categories from the Norwegian litter recording system (Ingris). In the following description variables used in the companion Excel spreadsheet are in **bold**. The order of variables in the companion spreadsheet follows the same order as they are arranged in the two input sources (The register for deliveries of carcasses to Norwegian slaughterhouses and Ingris). In list of variable names (Fig. 1), to ease the understanding of the description, the English names of the variables in the column B are coloured such that variable names in **red** are the variables that are used for the Sow category, numbers of (sow and year), only. Variable names used exclusively for the calculation (animal and year) for the Gilt category are coloured **blue**, for the Weaner category are coloured **green**, and for the Finisher category are coloured **purple**. Names of variables used in the calculation for more than one category are in black.

| Variable name | Variabel navn |
|---|---|
| | |
| **Number of finishers slaughtered** | Slaktestatistikk antall slaktegris |
| **Weaned piglets per (sow and year)** | Beregna avvente per årspurke |
| **Estimated number of finishers slaughtered per (sow and year)** | Beregna slakta slaktegris per årspurke |
| **First litter percentage** | Prosent 1. kull |
| **Litters per (sow and year)** | Kull per årspurke |
| **Age at first farrowing** | Inngrisingsalder |
| **Estimated number of finishers produced by a sow** | Livstidsproduksjon av slaktegris per purke |
| **Days of gestation** | Drektighetslengde |
| **Age at conception** | Bedekningsalder |
| **Age at entrance of gilt phase (about 120 kg LW)** | Alder rekruttstart (ca 120 kg levendevekt) |
| **Estimated number of gilt days** | Dager rekrutt |
| **(sow and year) per finisher slaughtered** | **Purke, årsdyr per slakta slaktegris** |
| **Gilt days per slaughtered finisher** | **Rekrutt, dager per slakta slaktegris** |
| **(gilt and year) per slaughtered finishers** | **Rekrutt, årsdyr per slakta slaktegris** |
| **Weight at entrance of weaner phase, kg** | Vekt ved innsett, kg |
| **Weight by end of weaner phase, kg** | Vekt ved avgang, kg |
| **Daily LW gain weaners, g** | Daglig tilvekst, gram |
| **FU per kg DLWG, weaners** | FEn per kg tilvekst |
| **Time in weaner phase** | Fôrdager per smågris |
| **Mortality weaners** | Døde, % |
| **Proportion of weaners required for the replacement** | Andel rekrutter % |
| **Weaners, days per slaughtered finisher** | **Smågris, dager per slakta slaktegris** |
| **LW at entrance of finisher phase, kg** | Vekt ved innsett, kg |
| **LW at slaughtering, kg** | Levendevekt, kg |
| **Daily LW gain finishers, g** | Daglig tilvekst, gram |
| **FU per kg DLWG, finishers** | FEn per kg tilvekst |
| **Time in finisher phase** | Døde, % |
| **Mortality finishers** | Andel rekrutter % |
| **Finishers, days per slaughtered finisher** | **Slaktegris, dager per slakta slaktegris** |
| **(finishers and year) per slaughtered finisher** | **Slaktegris, årsdyr per slakta slaktegris** |
| **Total number (sow and year)** | **Purke, antall årsdyr** |
| **Total number (gilt and year)** | **Rekrutt, antall årsdyr** |
| **Total number (weaner and year)** | **Smågris, antall årsdyr** |
| **Total number (finisher and year)** | **Slaktegris, antall årsdyr** |

**Figure 1. List of variable names used in the companion Excel spreadsheet for estimating animal numbers. The order of the variables corresponds to the structure of the spreadsheet for calculation of the numbers of animals throughout the year, as (animal and year), for four categories of pigs based on the register for deliveries of carcasses to slaughterhouses and the Ingris statistics. To ease the understanding of the description, separate colours for each animal category are used for the English names of the variables.**

Estimating numbers of animals in the Sows category as (sow and year) per finisher slaughtered: The input variable **Weaned piglets per (sow and year)** is from Ingris. In Ingris this variable is calculated by taking into account the mortality, slaughtering, and replacement rates of sows such that (sow and year) represent an animal throughout 365 days and not the number of individual animals. Based on **Weaned piglets per (sow and year)**, the variable **Estimated number of finishers slaughtered per (sow and year)** is calculated in the Excel spreadsheet by adjusting with percentage **Mortality weaners** and **Mortality finishers** from Ingris. The variable **(sow and year) per finisher slaughtered** is the inverse value of **Estimated number of finishers slaughtered per (sow and year).**

The total population of sows expressed as **Total number (sow and year)** is calculated by multiplying the Ingris derived variable **(sow and year) per finisher slaughtered** with **Number of finishers slaughtered** from the register for deliveries of carcasses to Norwegian slaughterhouses. The variable **Total number (sow and year)** represents the yearly number of sows that is needed as input (activity data) for the NIR.

Equations:

**Total number (sow and year)** = **(sow and year) per finisher slaughtered** x **Number of finishers slaughtered**

**(sow and year) per finisher slaughtered** = 1 / **Estimated number of finishers slaughtered per (sow and year)**

**Estimated number of finishers slaughtered per (sow and year)** = **Weaned piglets per (sow and year)** x (1 **- Mortality weaners**) x (1 **- Mortality finishers**)

Data sources:

**Number of finishers slaughtered,** The register for deliveries of carcasses to Norwegian slaughterhouses, Statistics Norway

**Weaned piglets per (sow and year)**, Ingris, the Norwegian Meat and Poultry research Centre

**Mortality weaners**, Ingris, the Norwegian Meat and Poultry research Centre

**Mortality finishers**, Ingris, the Norwegian Meat and Poultry research Centre

Estimating numbers of animals in the Gilts category as (gilt and year) per finisher slaughtered: The pig is categorized as a gilt in the period from **Age at entrance of gilt phase (about 120 kg LW)** to the **Age at conception**, and the length of the period is expressed as **Estimated number of gilt days** in the Excel spreadsheet**. Age at conception** is calculated as **Age at first farrowing** minus **Days of gestation**. After the first conception resulting in a litter the animal is entering the sow phase. Note that **Estimated number of gilt days** is lower for 1990 than 2020, this is due to the shortening of the **Time in weaner phase** and the **Time in finisher phase**.

As a first step towards the estimate of the proportion of weaners required for the replacement for sows leaving production, the variable **Estimated number of finishers produced by a sow** during lifetime is calculated as **Estimated number of finishers slaughtered per (sow and year)** divided on the number of **Litters per (sow and year)** and multiplied by (100 / **First litter percentage**). Then the variable **Gilt days per slaughtered finisher** is calculated as **Estimated number of gilt days** divided on **Estimated number of finishers produced by a sow**.

The estimate of **(gilt and year) per slaughtered finisher** is then calculated by dividing **Gilt days per slaughtered finisher** on 365 days. The total population of gilts expressed as **Total number (gilt and year)** is calculated by multiplying the Ingris derived variable **(gilt and year) per finisher slaughtered** with **Number of finishers slaughtered** from the register for deliveries of carcasses to Norwegian slaughterhouses. The variable **Total number (gilt and year)** represents the yearly number of gilts that is needed as input (activity data) for the NIR.

Equations:

**Total number (gilt and year) = (gilt and year) per finisher slaughtered** x **Number of finishers slaughtered**

**(gilt and year) per slaughtered finisher** = **Gilt days per slaughtered finisher** / 365

**Gilt days per slaughtered finisher = Estimated number of gilt days** / **Estimated number of finishers produced by a sow**

**Estimated number of finishers produced by a sow = Estimated number of finishers slaughtered per (sow and year)** / **Litters per (sow and year)** x (100 / **First litter percentage**)

**Estimated number of finishers slaughtered per (sow and year)** = **Weaned piglets per (sow and year)** x (1 **- Mortality weaners**) x (1 **- Mortality finishers**)

**Estimated number of gilt days = Age at conception - Age at entrance of gilt phase (about 120 kg LW)**

**Age at conception = Age at first farrowing - Days of gestation**

Data sources:

**Number of finishers slaughtered,** The register for deliveries of carcasses to Norwegian slaughterhouses, Statistics Norway

**Litters per (sow and year)**, Ingris, the Norwegian Meat and Poultry research Centre

**First litter percentage**, Ingris, the Norwegian Meat and Poultry research Centre

**Weaned piglets per (sow and year)**, Ingris, the Norwegian Meat and Poultry research Centre

**Mortality weaners**, Ingris, the Norwegian Meat and Poultry research Centre

**Mortality finishers**, Ingris, the Norwegian Meat and Poultry research Centre

**Age at first farrowing,** Ingris, the Norwegian Meat and Poultry research Centre

**Days of gestation,** Ingris, the Norwegian Meat and Poultry research Centre

Estimating numbers of animals in the Weaners category as (weaner and year) per finisher slaughtered:
To estimate the days a slaughtered finisher is in the weaner category, the variable **Weaners, days per slaughtered finisher** is calculated as (**Weight by end of weaner phase, kg** minus **Weight at entrance of weaner phase, kg** multiplied by 1000) divided on **Daily LW gain weaners, g**, and adjusted with percentage **Mortality weaners**, and the **Proportion of weaners required for the replacement** for sows leaving production. Note that as some animals die early whereas others late in the period, the **Mortality weaners** is halved to avoid underestimation of the animal numbers.

The estimate of **(weaner and year) per slaughtered finisher** is then calculated by dividing **Weaners, days per slaughtered finisher** on 365 days. The total population of weaners expressed as **Total number (weaner and year)** is calculated by multiplying the Ingris derived variable **(weaner and year) per finisher slaughtered** with **Number of finishers slaughtered** from the register for deliveries of carcasses to Norwegian slaughterhouses. The variable **Total number (weaner and year)** represents the yearly number of weaners that is needed as input (activity data) for the NIR.

Equations:

**Total number (weaner and year) = (weaner and year) per finisher slaughtered** x **Number of finishers slaughtered**

**(weaner and year) per finisher slaughtered** = **Weaners, days per slaughtered finisher** / 365

**Weaners, days per slaughtered finisher** = ((**Weight by end of weaner phase, kg** - **Weight at entrance of weaner phase, kg)** x 1000 / **Daily LW gain weaners, g**,) / (1 – (**Mortality weaners** x 0.5) - **Proportion of weaners required for the replacement)**

**Proportion of weaners required for the replacement** = 1 / **Estimated number of finishers produced by a sow**

Data sources:

**Number of finishers slaughtered,** The register for deliveries of carcasses to Norwegian slaughterhouses, Statistics Norway

**Weight by end of weaner phase, kg**, Ingris, the Norwegian Meat and Poultry research Centre

**Weight at entrance of weaner phase**, Ingris, the Norwegian Meat and Poultry research Centre

**Daily LW gain weaners, g**, Ingris, the Norwegian Meat and Poultry research Centre

**Mortality weaners**, Ingris, the Norwegian Meat and Poultry research Centre

**Estimated number of finishers produced by a sow,** estimated from Ingris, the Norwegian Meat and Poultry research Centre, see box above

Estimating numbers of animals in the Finishers category as (finisher and year) per finisher slaughtered: To estimate the days a slaughtered finisher is in the finisher category, the variable **Finishers, days per slaughtered finisher** is calculated as (**LW at slaughtering, kg** minus **LW at entrance of finisher phase, kg** multiplied by 1000) divided on **Daily LW gain finishers, g**, and adjusted with percentage **Mortality finishers**, and proportion the **Proportion of weaners required for the replacement** for sows leaving production. Note that as some animals die early whereas others late in the period, the **Mortality finishers** is halved to avoid underestimation of the animal numbers.

The estimate of **(finishers and year) per slaughtered finisher** is then calculated by dividing **Finishers, days per slaughtered finisher** on 365 days. The total population of finishers expressed as **Total number (finisher and year)** is calculated by multiplying the Ingris derived variable **(finisher and year) per finisher slaughtered** with **Number of finishers slaughtered** from

the register for deliveries of carcasses to Norwegian slaughterhouses. The variable **Total number (finishers and year)** represents the yearly number of finishers that is needed as input (activity data) for the NIR.

Equations:

**Total number (finishers and year)** = **(finisher and year) per finisher slaughtered** x **Number of finishers slaughtered**

**(finisher and year) per finisher slaughtered** = **Finishers, days per slaughtered finisher** / 365

**Finishers, days per slaughtered finisher** = ((**LW at slaughtering, kg** - **LW at entrance of finisher phase, kg)** x 1000) / **Daily LW gain finishers, g**,) / (1- (**Mortality finishers** x 0.5) - **Proportion of weaners required for the replacement)**

Data sources:

**Number of finishers slaughtered,** The register for deliveries of carcasses to Norwegian slaughterhouses, Statistics Norway

**LW at slaughtering, kg**, Ingris, the Norwegian Meat and Poultry research Centre

**LW at entrance of finisher phase, kg**, Ingris, the Norwegian Meat and Poultry research Centre

**Daily LW gain finishers, g**, Ingris, the Norwegian Meat and Poultry research Centre

**Mortality finishers**, Ingris, the Norwegian Meat and Poultry research Centre

**Proportion of weaners required for the replacement,** estimated from Ingris, the Norwegian Meat and Poultry research Centre, see box above

## 3.2. Estimating CH4 emissions for four categories of pigs

Dynamic category specific emission factors of enteric $CH_4$ emissions are estimated for the four categories, Sows, Gilts, Weaners, and Finishers, following the approach of Philippe and Nicks (2015). The characterization of the emissions factors as dynamic implies that the emission factors change if there are changes in the yearly inputs to the equations that are used to estimate the emission factors. The yearly input factors that will change by progress in genetics and management are **Daily LW gain** and **FU per kg Daily LW gain** (see box below). This approach qualifies to the IPCC definition as Tier 2 as it at an intermediate level of complexity and require local and detailed production specific data. How the estimated emissions factors depend on the yearly inputs is described in detail in the following:

In this approach, the $CH_4$ emissions are calculated as the product of research-based factors accounting for fermentation in the large intestine and the daily intake of digestible fibre. The digestible fibre is defined as “the digestible residues” (dRes) and is calculated as the difference between digestible organic matter and digestible protein, fat, starch, and sugar. Typical values for the concentration of dRes in feed for the four categories of pigs were obtained from the two largest feed producing companies in Norway (pers. comm. Vidar Aglen, Felleskjøpet Agri SA; Inger Johanne Karlengen, Norgesfôr AS). In the Excel spreadsheet, **dRes percentage feed** for the four categories are: Sows, 12.5 %, Gilts, 10.75 %; Weaners, 8.0 %; Finishers, 10.75 % (Fig. 2). The dRes values obtained from the two companies were quite similar and it is assumed that these values do not vary much among years.

To estimate **Daily dRes intake g**, the **dRes percentage feed** is multiplied with **Daily feed intake kg** and 1000 g $kg^{-1}$. The **Daily feed intake kg** is based on the estimated **Daily energy intake FU**, expressed in feed units (FU) and the **FU concentration feed**. For the sow and gilt category **Daily energy intake FU** is obtained from typical numbers from Norwegian farms, and for weaner and finisher categories the values are calculated as the **Daily LW gain, g** multiplied with **FU per kg Daily LW gain** divided by 1000 g $kg^{-1}$, obtained from Ingris (Fig. 1).

The **Daily rate CH4 per (animal and day)** is calculated as the product of the category specific **Daily dRes intake g** and the **dRes factor**. Philippe and Nicks (2015) estimated the **dRes factor** to 0.021 g $CH_4$ $day^{-1}$ for sows, and 0.12 g $CH_4$ $day^{-1}$ for the categories of growing pigs. Yearly rates per (animal and year) is calculated by multiplying the daily rate by 365 days $year^{-1}$. For 2021 the **Yearly rate CH4 (sow and year)** was estimated to 3.6 kg $CH_4$ (sow and year)$^{-1}$, the **Yearly rate CH4 (gilt and year)** to 0.9 kg $CH_4$ (gilt and year)$^{-1}$, the **Yearly rate CH4 (weaner and year)** to 0.3 kg $CH_4$ (weaner and year)$^{-1}$, and the **Yearly rate CH4 (finisher and year)** to 1.3 kg $CH_4$ (finisher and year)$^{-1}$ (Fig. 2).

Equations:

**Daily rate CH4 per (animal and day)** = **Daily dRes intake g** x **dRes factor**

**Daily dRes intake** = **dRes percentage feed** x **Daily energy intake FU** / **FU concentration feed**

**Daily energy intake FU** = **Daily LW gain** x **FU per kg Daily LW gain**

Data sources:

**dRes factor**, Philippe and Nicks (2015)

**dRes percentage feed**, typical numbers form Norwegian feed producers

**FU concentration feed**, typical numbers form Norwegian feed producers

**Daily LW gain**, Ingris, the Norwegian Meat and Poultry research Centre

**FU per kg Daily LW gain**, Ingris, the Norwegian Meat and Poultry research Centre

| Variable name | Variabel navn |
|---|---|
| | |
| **dRes percentage feed, Sows** | Purke, dRes-prosent i fôr |
| **dRes percentage feed, Gilts** | Rekrutt, dRes-prosent i fôr |
| **dRes percentage feed, Weaners** | Smågris, dRes-prosent i fôr |
| **dRes percentage feed, Finishers** | Slaktegris, dRes-prosent i fôr |
| | |
| **Daily energy intake FU, Sows** | Purke, daglig fôropptak i Fen |
| **Daily energy intake FU, Gilts** | Rekrutt, daglig fôropptak i Fen |
| **Daily energy intake FU, Weaners** | Smågris, daglig fôropptak i Fen |
| **Daily energy intake FU, Finishers** | Slaktegris, daglig fôropptak i Fen |
| | |
| **Daily feed intake kg , Sows** | Purke, daglig fôropptak i kg |
| **Daily feed intake kg, Gilts** | Rekrutt, daglig fôropptak i kg |
| **Daily feed intake kg, Weaners** | Smågris, daglig fôropptak i kg |
| **Daily feed intake kg , Finishers** | Slaktegris, daglig fôropptak i kg |
| | |
| **Daily dRes intake g, Sows** | Purke, daglig dRes_opptak i g |
| **Daily dRes intake g, Gilts** | Rekrutt, daglig dRes_opptak i g |
| **Daily dRes intake g, Weaners** | Smågris, daglig dRes_opptak i g |
| **Daily dRes intake g, Finishers** | Slaktegris, daglig dRes_opptak i g |

**Figure 2. List of variable names in English and Norwegian, used in the companion Excel spreadsheet for estimating enteric methane per (animal and year) for four categories of pigs, based on Ingris statistics.**

# 4. Discussions

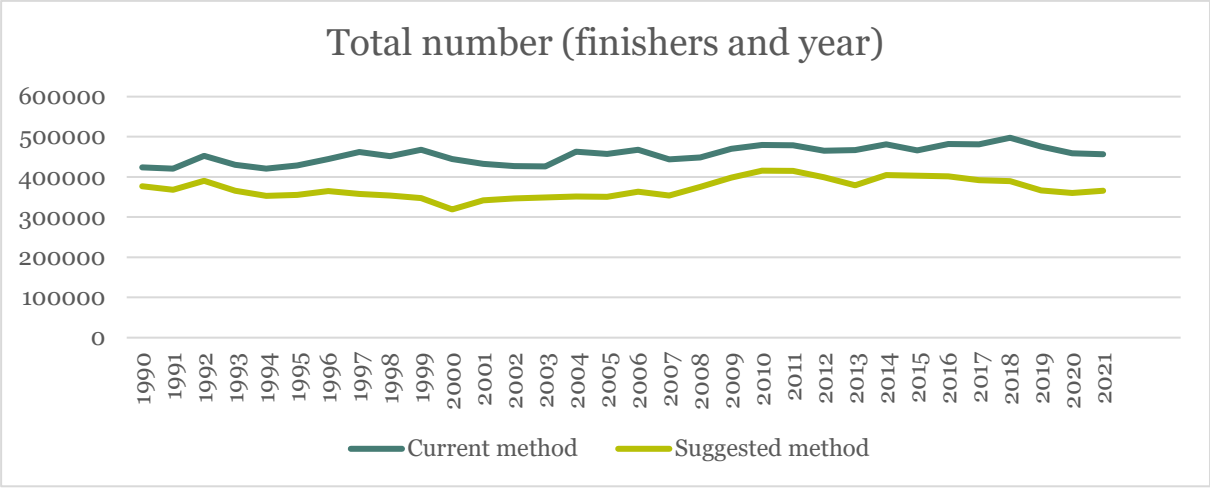
The methodology suggested herein is based on the total number of slaughtered finishers from the register for deliveries of carcasses to slaughterhouses. This approach provides a reliable estimate of the size of the Norwegian pork production. The estimate of the composition of the pig population based on the Ingris is robust enough to provide number of animals in each of the specified animal categories.

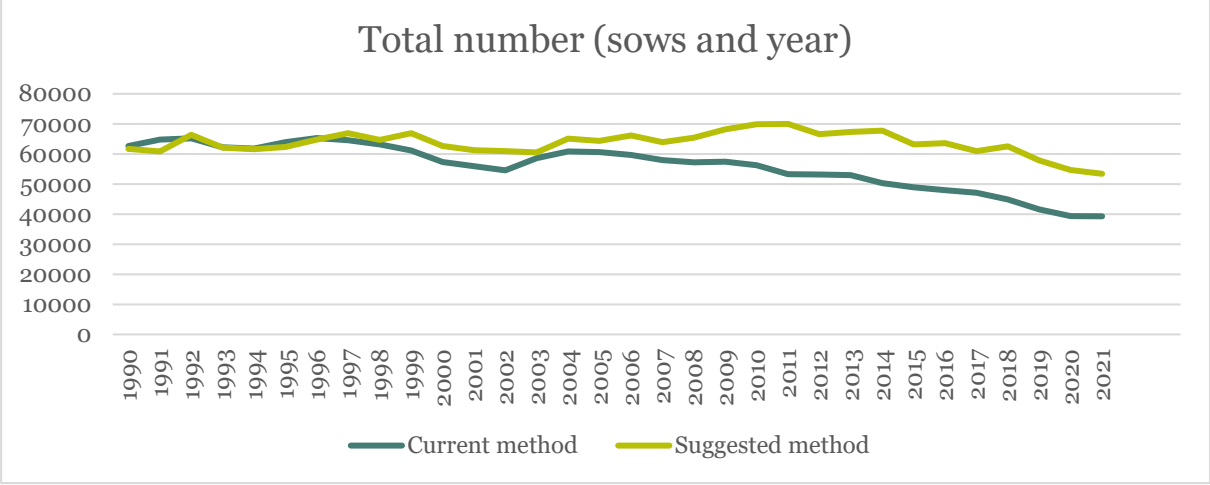
Commercial pig units are organized as independent family farms with either specialized piglet production, grower-finisher production, or combined production. Of the elements in this production system, the management of the sows is the most challenging and are causing a larger part of the variation among pig units' performance. As Ingris covers more than 70 % of the national population of sows, the sample is assumed large enough to reflect the variation of the whole population. This assumption is strengthened by the fact that several of the pig producers who are not use Ingris use other systems instead (*e.g*. the Danish Agrosoft system), showing that the group that do not use Ingris is a mix of some of the best performing units and units without any production planning systems.

The variation among farms in the other parts of the production system, the weaners and finisher, is smaller. It is therefore assumed that the estimates of the numbers of (animal and year) of these categories are representative although the participation in the Ingris system is smaller. A quantitative assessment of representativeness was conducted for 2020 by comparing the estimated concentrate feed per kg pork carcass from the Ingris system with the concentrate feed per kg carcass calculated for the whole population by using statistics of total pork carcasses delivered and feed sold. The difference between the result of the two methods was small. The Ingris number of 3.9 kg concentrate feed per kg carcass was at the same level as the number of 3.89 kg concentrate feed per calculated on the basis of the total population.

By implementing the suggested methodology, the NIR will reflect the progress in the pork production system, accounting for the effect of ongoing and future measures for a more effective production system regarding the GHG emissions (see Bonesmo & Enger, 2021). Ongoing measures are breeding for higher performance, and management system for improved animal health. A future measure, still at research stage, is the finishing of uncastrated males. Yet, it is noteworthy that even if the estimates of numbers of animals is improved, the uncertainty connected to the largest emissions sources of the pig production system, manure storage and handling, is large. This is due to the high uncertainty of the emission factors of the pig manure system (Rivedal et al., 2022). There are also some measures for reducing GHG emission per kg carcass weight (CW) that will not be reflected in the NIR, as these are measures that will reduce GHG emissions in other countries (Øygarden et al., 2022).

Comparing the development from 1990 to present of the animal numbers estimated by using the current Norwegian NIR method with the animal numbers estimated by the suggested method, both methods result in relatively stable level of **Total number (finishers and year)** (Fig. 3). The stable level of **Total number (finishers and year)** despite the increase of the production of pork CW by 66 % (combination of number of slaughtered finishers and weight of carcasses) is caused by the change in daily growth for finishers from 650 g per day in 1990 to 1084 g per day in 2022. During the period the CW per finishers has increased by 17% and the number of slaughtered finishers has gone from 1059000 to 1505436. These quite large changes balance out each other such that the **Total number (finishers and year)** has remained relatively stable throughout the period.



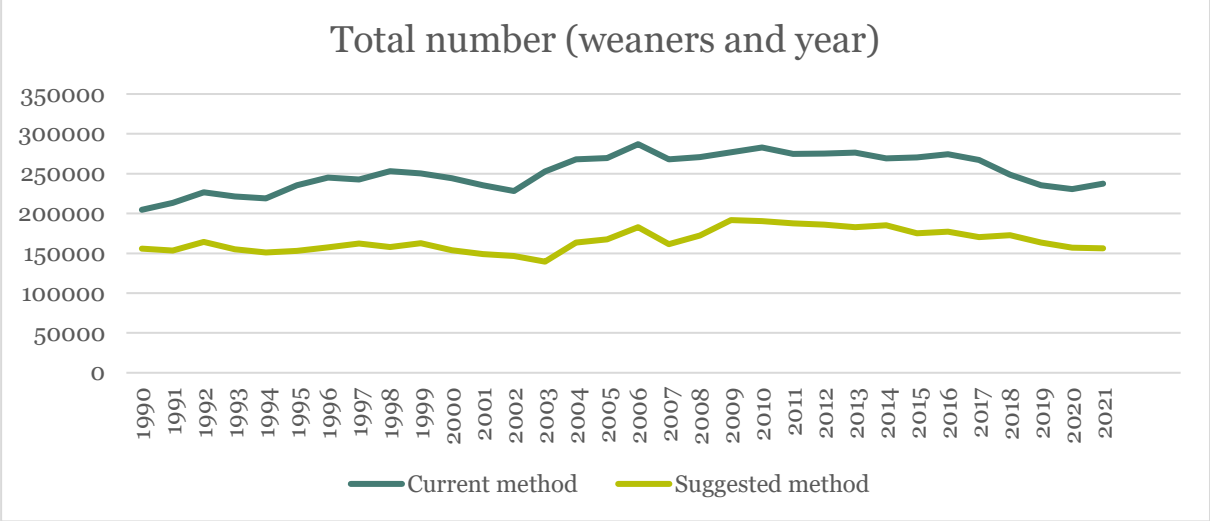




**Figure 3. Estimates of numbers of animals for three categories of pigs, based on current and suggested methodology for activity data to NIR.**

The difference in level in **Total number (finishers and year)** between the two methods emerge from the basic difference in approach. The current method is based on the assessment of batches per year, changing from 2.5 in 1990 to 3.3 in 2021, where the numbers of day per slaughtered finishers is estimated as 365 days per year divided on the number of batches per year. This result in 146 days per slaughtered finisher in 1990 and 111 days in 2021. However, due to the limitations caused by the sow

cycle (time of pregnancy and suckling) the number of batches per year has not really increased, such that a methodology for estimating (animals and year) should not be based on the assessment of batches per year.

The suggest methodology is, on the other hand, not based on assessments but on measured and reported production characteristics. These are **Number of finishers slaughtered from** the register for deliveries of carcasses to Norwegian slaughterhouses of Statistics Norway, and **LW at slaughtering, LW at entrance of finisher phase, Daily LW gain finishers,** and **Mortality finishers** from the Norwegian Meat and Poultry research Centre, see text and box with equations in previous chapter for details. By using the suggested methodology, the estimated numbers of day (**Total number (finishers and year)**) per slaughtered finishers changes from 130 in 1990 to 89 in 2021. When the daily growth is higher without the possibility of increasing the number of batches per year, this will necessarily lead to fewer days of production and more non-productive days per batch. Thus, the approach based on the reported and measured production characteristics gives a more robust and reliable estimate for the **Total number (finishers and year)** for a progressive production system.

Similarly, the number of weaners as **Total number (weaners and year)** will be lower by using the suggested methodology. This is reasonable since the daily growth rate for weaners has increased from 362 g per day in 1990 to 598 g per day in 2021, and this increase comes as consequence of progress in genetics and management that has been ongoing also earlier than 1990. For the estimated **Total number (sows and year)**, the use of the suggested methodology will result in higher numbers than the use of the current methodology, whereas there will be a lower value for **Total number (gilts and year)**. However, both methods give equivalent numbers for the sum of **Total number (sows and year)** and **Total number (gilts and year).** This comes from the definitions of the pig categories: In the current methodology, the animal is defined as a gilt until first parturition. In the suggested methodology, the animal is categorized as gilt until first insemination. Note that in the suggested methodology, the period where the animal is categorized as gilt is from the day where animal reaches 120 kg LW; prior to 120 kg LW the animal is included in the weaner and finisher categories. By using the suggested methodologies for estimating animal numbers and enteric $CH_4$ emissions, there will be a higher estimate of emissions, compared with the current methodology, for the sum of the sows and gilt categories as the emission factor for sows are significantly higher than that of gilts (Table 1).

The general Tier 1 emission factor of IPCC (Eggleston et al., 2006) of 1.5 kg $CH_4$ per (animal and year) is currently used in the Norwegian NIR. The general emission factor intends to cover all categories of pigs. Among the Nordic countries, the general IPCC emission factor is used in the NIRs of Sweden and Norway, whereas category specific emissions factors are used for pigs in the NIRs of Denmark and Finland (Table 1). Using the methodology suggested in the current work, the estimates of category specific emission factors for Norwegian pig production will be at the same level as the average of the factors of Denmark and Finland. The variation in the factors among the three countries may be attributed to differences in the definitions in weights and ages by entrance into, and exit from, the categories.

**Table 1. Emission factors for enteric methane, kg CH4 (animal and year)-1, for categories of pigs, for the GHG NIRs of four Nordic countries.**

| | Norway, currently | Norway, suggested[1] | Denmark | Finland | Sweden |
|---|---|---|---|---|---|
| **Sows** | 1.5 | 3.6 | 2.75 | 3.8 | 1.5 |
| **Boars** | 1.5 | 2.9 | not included | 3.6 | 1.5 |
| **Weaners** | 1.5 | 0.3 | 0.42 | 0.1 | 1.5 |
| **Finishers** | 1.5 | 1.3 | 1.53 | 1.2 | 1.5 |
| **Gilts** | not included | 0.9 | not included | not included | 1.5 |

*[1] The suggested emission factors are calculated for 2021 and may slightly change, as described in the current report, with progress in pig genetics and management. For the Boars category, the emission factor is set to 80% of that for Sows, based on the relative difference in feed intake.*

In the Nordic countries, the animal performance in pork production is high in terms of reproduction, growth, and health. As noted in the Danish NIR, the number of young animals relative to the number of sows will be higher than world average. Thus, using specific emissions factors for pig categories will be a better estimate for the GHG emissions from pork production, than using the general factor.

# References

Bonesmo, H., Beauchemin, K. A., Harstad, O. M., & Skjelvåg, A. O. (2013). Greenhouse gas emission intensities of grass silage based dairy and beef production: A systems analysis of Norwegian farms. Livestock Science, 152(2-3), 239-252.

Bonesmo, H., & Enger, E. G. (2021). The effects of progress in genetics and management on intensities of greenhouse gas emissions from Norwegian pork production. Livestock Science, 254, 104746.

Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). 2006 IPCC guidelines for national greenhouse gas inventories.

Norwegian Environment Agency, Norwegian Institute of Bioeconomy Research, Statistics Norway. (2020). Greenhouse Gas Emissions 1990‐2018, National Inventory Report. M ‐ 1654, 1-567.

Philippe, F. X., & Nicks, B. (2015). Review on greenhouse gas emissions from pig houses: Production of carbon dioxide, methane and nitrous oxide by animals and manure. Agriculture, Ecosystems & Environment, 199, 10-25.

Rivedal, S., Bechmann, M., & Kvifte, Å. M. (2022). Husdyrgjødseltiltak og klimagassutslepp. Vurdering av årlege aktivitetsdata og ein del utsleppsfaktorar. NIBIO Rapport, Vol 8 (20) 46 s.

Øygarden, L., Aass, L., Bakken, A. K., Bonesmo, H., Geipel, J., & Åby, B. A. (2022). Indikatorer og metoder for dokumentasjon og tiltaksrapportering i Klimaavtalen og indirekte effekt av tiltak. NIBIO Rapport, Vol 8 (129).

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