**MPI Policy and Trade**

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# Update to dairy manure and effluent management practices

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**Purpose of this paper**

1. This paper seeks a recommendation from the Panel on whether to update the treatment of dairy manure management practices in the national greenhouse gas inventory. These changes are:

    a) Updated activity data on manure from off-paddock facilities (e.g., feed pads, stand-off pads, housing) into the manure management system methodology for mature milking cows.

    b) Allocating collected manure between anaerobic lagoons and solid storage.

    c) Introducing emission factors for manure in solid storage.

    d) Introducing seasonal allocation of total annual dairy manure entering manure management systems.

2. Including the updated annual estimates of dairy manure directed to anaerobic lagoons and solid storage would reduce reported emissions by approximately 107 kilotonnes (kt) of carbon dioxide equivalent ($CO_2$-e) in 2023. This equates to a decrease in total reported agricultural emissions of 0.26%. This change increases over time as off-paddock facilities become more widely used.

3. Seasonal allocation of the revised annual estimates of dairy manure directed to anaerobic lagoons and solid storage has a small impact. Seasonal allocation increases reported emissions by approximately 7 kt $CO_2$-e in 2023. The net effect of both changes is a total reduction of 100 kt $CO_2$-e.

4. Attached to this paper are the following:

    a) Luo et.al. (2025). Manure Management Systems – Final report; Report for Ministry for Primary Industries (unpublished),

    b) Review of report by Russ Tillman,

    c) Inventory change approval form completed by Russ Tillman, and

d) Response to feedback from MPI and Tillman by Luo.

## Background – Activity data on dairy effluent management

5. Prior to the 2019 inventory submission, the inventory assumed that 6% of the manure produced by lactating cattle was stored in anaerobic lagoons (Ledgard & Brier, 2004). In 2019 the inventory was updated to assume that from 2015 onward 8.5% of the manure from lactating cattle is directed to anaerobic lagoons (Rollo, Ledgard and Longhurst, 2017).

*Table 1: Current annual proportion of lactating cattle manure to management systems*

| Year | Anaerobic lagoon $MS_{AL,CH4}$ | Pasture, range and paddock $MS_{PRP}$ |
|---|---|---|
| **1990-2004** | *5.779%* | *94.221%* |
| **2005** | *5.838%* | *94.162%* |
| **2006** | *5.906%* | *94.094%* |
| **2007** | *5.993%* | *94.007%* |
| **2008** | *6.109%* | *93.891%* |
| **2009** | *6.264%* | *93.736%* |
| **2010** | *6.466%* | *93.534%* |
| **2011** | *6.726%* | *93.274%* |
| **2012** | *7.052%* | *92.948%* |
| **2013** | *7.455%* | *92.545%* |
| **2014** | *7.942%* | *92.058%* |
| **2015-2023** | *8.525%* | *91.475%* |

6. In 2023 MPI commissioned AgResearch to provide updated data on dairy manure management practices.

7. The attached report (Luo, et al., 2025) contains the findings of this project. The report focuses on off-paddock structures and does not revise data relating to milking sheds.

## Proposed change – Updated activity data on dairy effluent management

8. Luo et al. (2025) analysed detailed data from all Fonterra farms for the 2022–2023 year. The assessment included farm distribution, the number of lactating cows, and the presence of three types of off-paddock facilities: feed pads, stand-off loafing pads, and livestock housing.

9. The data covered 8,454 farms with a total of 3,774,679 lactating cows at peak milking.

10. 34% of farms had at least one type of off-paddock facility.

a) 22% had feed pads,

b) 14% had stand-off loafing pads, and

c) 6% had livestock housing.

11. Across all Fonterra farms, cows spent approximately 2.7% of their time annually in off-paddock facilities. As a result, it was assumed that 2.7% of mature milking cow manure was deposited in these facilities each year. The manure deposited on off paddock facilities was divided between feed pad, stand-off or loafing pads and housing facilities using a similar cow hours approach. The break down is as follows:

a) 1.54% on feed pads,

b) 0.30% on stand-off or loafing pads,

c) 0.85% in housing facilities.

12. According to Rollo et al. (2017), 6.41% of manure from lactating cows was deposited in milking sheds annually. However, these fractions may have changed in recent years. Updated information, including changes in herd management practices, milking frequencies, and shifts in dairy cow breed, would be necessary to reassess and recalculate these values.

*Table 2: Summary of suggested proportions for mature milking cows 2022–2023*

| Structure | Annual proportion of mature milking cow manure |
|---|---|
| **Feed pad** | 1.54% |
| **Stand-off loafing pad** | 0.30% |
| **Housing** | 0.85% |
| **Milking shed** | 6.41% |
| **Total** | 9.10% |

13. Eight experts provided their opinions on the proportions of dairy excreta stored as "liquid", "slurry", and "solids". The experts brought a diverse range of expertise in farm dairy effluent collection, storage, and application. Due to privacy concerns, most respondents preferred not to be directly named in the report. The responses are presented in Table 3.

14. The original intent was to survey farms on off-paddock facilities, usage, and effluent management, but data from initial 60 farms proved unreliable despite extensive follow-up. After consultation with MPI, surveys were discontinued and expert opinions used instead.

*Table 3: Estimated % of how effluent is stored from different collection sources.*

| | Storage | Waikato (n=4) | Manawatū (n=2) | Otago (n=1) | Southland (n=1) |
|---|---|---|---|---|---|
| **Milking shed effluent** | Liquid | 95-100 | 100 | 70 | 95 |
| | Slurry | 0-1 | 0 | 5 | 0 |
| | Solid | 0-3 | 0 | 25 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| **Stand-off pads** | Liquid | 0 | | 10 | |
| | Slurry | 0 | | 0 | |
| | Solid | 95-100 | | 90 | |
| **Feed pads** | Liquid | 55-65 | 84 | 15 | 75 |
| | Slurry | 5-15 | 0 | 0 | 0 |
| | Solid | 25-35 | 16 | 85 | 25 |
| **Animal shelters/housing** | Liquid | 5-15 | | 60 | 55 |
| | Slurry | 15-25 | | 5 | 0 |
| | Solid | 65-75 | | 35 | 45 |

15. There was considerable variation in the reported percentages of different manure forms associated with off-paddock facilities. This uncertainty stems from the limited number of expert contributors, which restricts the ability to calculate reliable averages or quantify statistical uncertainty. Most experts agreed that robust data collection from farms is essential to address this gap.

16. From these expert opinions the following divisions between liquid and solid forms by collection structure were derived for inclusion in the Inventory:

*Table 4: Division between solid and liquid/slurry for manure from structures*

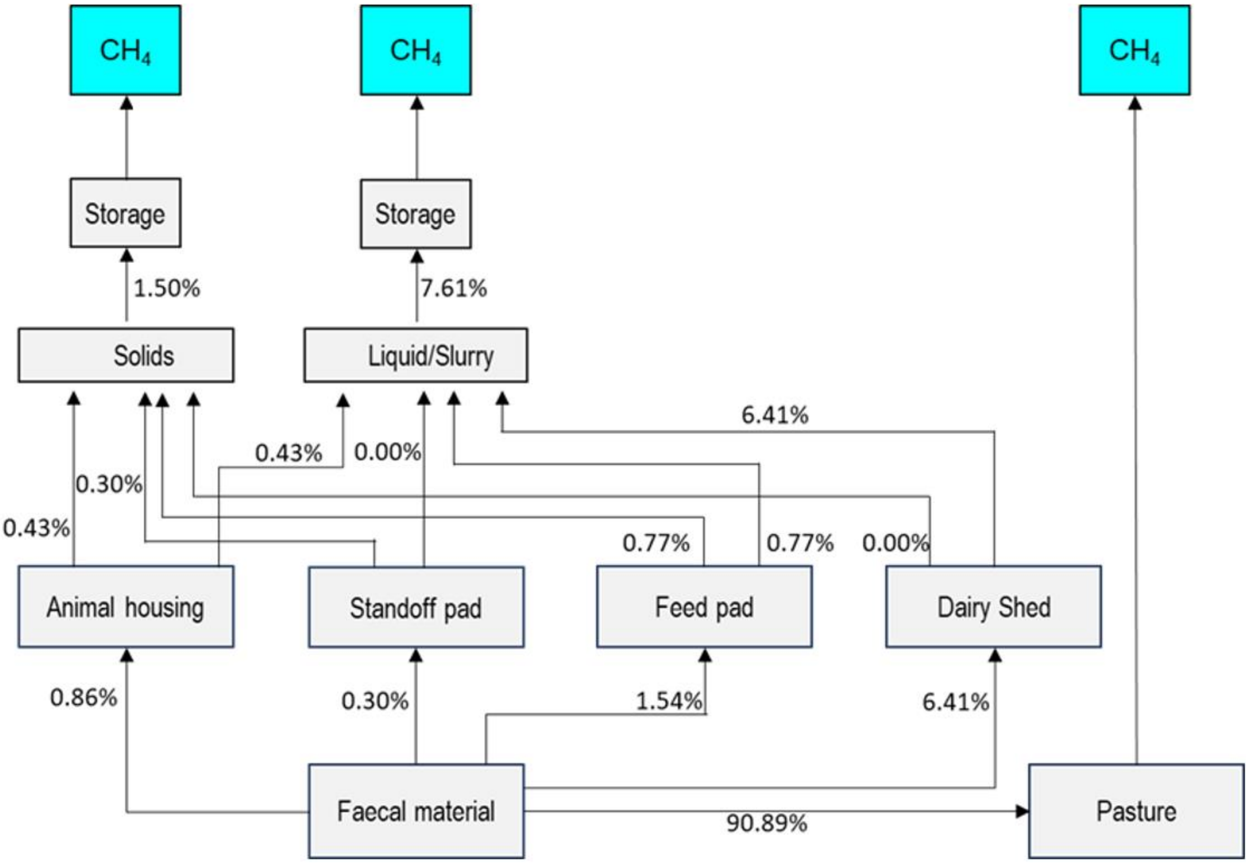
| Structure | Solid | Liquid/Slurry |
|---|---|---|
| **Housing** | 50% | 50% |
| **Stand-off loafing pad** | 100% | 0% |
| **Feed pad** | 50% | 50% |
| **Milking shed** | 0% | 100% |

17. Of the total manure produced by mature milking cows, 7.61% is stored in liquid/slurry form, while 1.50% is stored as solid manure. A detailed breakdown by collection structure is provided in Table 5.

*Table 5: proportion of mature milking cow excreta by collection structure and form stored*

| Structure | Total | Solid (solid storage) | Liquid/Slurry (anaerobic lagoon) |
|---|---|---|---|
| **Housing** | 0.85% | 0.43% | 0.43% |
| **Stand-off loafing pad** | 0.30% | 0.30% | 0.00% |
| **Feed pad** | 1.54% | 0.77% | 0.77% |
| **Milking shed** | 6.41% | 0.00% | 6.41% |
| **Total** | 9.10% | 1.50% | 7.61% |

*Figure 1: Revised framework for calculating $CH_4$ emissions from MMSs including proportions of dairy manure entering various streams.*




18. The report recommends extending the framework developed by Rollo et al. (2017) to incorporate updated data on manure allocation to different manure management systems (MMS). Specific recommendations by time period are as follows:

    a) 1990-2004: No changes to current inventory assumptions are proposed for this period. Consistent with Rollo et al. (2017), off-paddock facility use is assumed to be zero prior to 2005. Therefore, all manure from milking sheds is allocated to anaerobic lagoons.

    b) 2005–2016: Apply off-paddock facility usage data from Rollo et al. (2017). Using the framework outlined in Luo et al. (2025), manure from off-paddock facilities and milking sheds can be allocated to either liquid/slurry or solid storage. These estimates are presented in Table 6.

    c) 2017–2022: Use linear interpolation between 2016 and 2022/2023 to estimate the proportion of manure from off-paddock facilities entering different MMSs. These interpolated values are shown in Table 7. Apply the milking shed proportion consistent with Rollo et al. (2017).

    d) From 2023 onward: implement the proposed framework and 2023 activity data as described Luo et al. (2025).

*Table 6: Data from Rollo et al. (2017) Fraction of manure deposited in different systems – lactating cows only (%). Applying same distribution to solid and liquid/slurry as specified in Luo et al. (2025).*

| Year | Milking shed | Feed pad | Stand-off loafing pad | Housing | | | | Total | Solid | Liquid /Slurry |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Wintering | Bedding | Slatted Concrete | Free stalls | | | |
| **2005** | 5.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 5.84% | 0.00% | 5.8% |
| **2006** | 5.9% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 5.91% | 0.01% | 5.9% |
| **2007** | 6.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 5.99% | 0.02% | 6.0% |
| **2008** | 6.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 6.11% | 0.06% | 6.1% |
| **2009** | 6.1% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 6.26% | 0.11% | 6.2% |
| **2010** | 6.1% | 0.2% | 0.0% | 0.0% | 0.1% | 0.1% | 0.0% | 6.47% | 0.19% | 6.3% |
| **2011** | 6.2% | 0.3% | 0.1% | 0.0% | 0.1% | 0.1% | 0.0% | 6.73% | 0.30% | 6.4% |
| **2012** | 6.2% | 0.4% | 0.1% | 0.0% | 0.1% | 0.2% | 0.0% | 7.05% | 0.45% | 6.6% |
| **2013** | 6.3% | 0.5% | 0.1% | 0.1% | 0.2% | 0.2% | 0.0% | 7.45% | 0.64% | 6.8% |
| **2014** | 6.4% | 0.7% | 0.2% | 0.1% | 0.2% | 0.3% | 0.0% | 7.94% | 0.88% | 7.1% |
| **2015** | 6.4% | 1.0% | 0.2% | 0.1% | 0.3% | 0.4% | 0.1% | 8.52% | 1.17% | 7.4% |
| **2016** | 6.4% | 1.0% | 0.2% | 0.1% | 0.3% | 0.4% | 0.1% | 8.52% | 1.17% | 7.4% |

*Table 7: Interpolated values between 2016 and 2023**

| Year | Total | Solid | Liquid/Slurry |
|---|---|---|---|
| **2016** | 8.52% | 1.17% | 7.36% |
| **2017** | 8.61% | 1.22% | 7.39% |
| **2018** | 8.69% | 1.26% | 7.43% |
| **2019** | 8.77% | 1.31% | 7.46% |
| **2020** | 8.86% | 1.36% | 7.50% |
| **2021** | 8.94% | 1.40% | 7.54% |
| **2022** | 9.02% | 1.45% | 7.57% |
| **2023*** | 9.10% | 1.50% | 7.61% |

*2023 values based on Luo et al. (2025), 2017-2022 values interpolated

**Proposed change – Emission factors for solid storage**

19. Luo et al. (2025) does not recommend any changes to the existing emission factors for anaerobic lagoons. However, since solid storage is being introduced as a new manure management system for dairy in the inventory, appropriate emission factors are required to estimate both methane and nitrous oxide emissions. In the absence of country-specific data, it is proposed that default values from the 2019 IPCC Guidelines be used.

*Solid storage methane conversion factor (MCF)*

20. The 2019 Refinement to the IPCC Guidelines revised the approach to MCFs, recommending disaggregation by climate zone rather than by average annual temperature. The guidance states that, where countries span multiple climate zones, it is good practice to disaggregate livestock populations accordingly.

21. Figure 10A.1 of the 2019 Refinement was used to identify the dominant climate zone for each region of New Zealand. These zones were then used to assign appropriate MCF values. The results of this interpretation are presented in Table 8.

*Solid storage direct nitrous oxide emissions (EF3)*

22. Table 10.21 in the 2019 refinement has a default EF3 for solid storage of 0.010 kg N2O-N per kg nitrogen excreted.

*Figure 2: New Zealand section – mapping of IPCC climate zones*

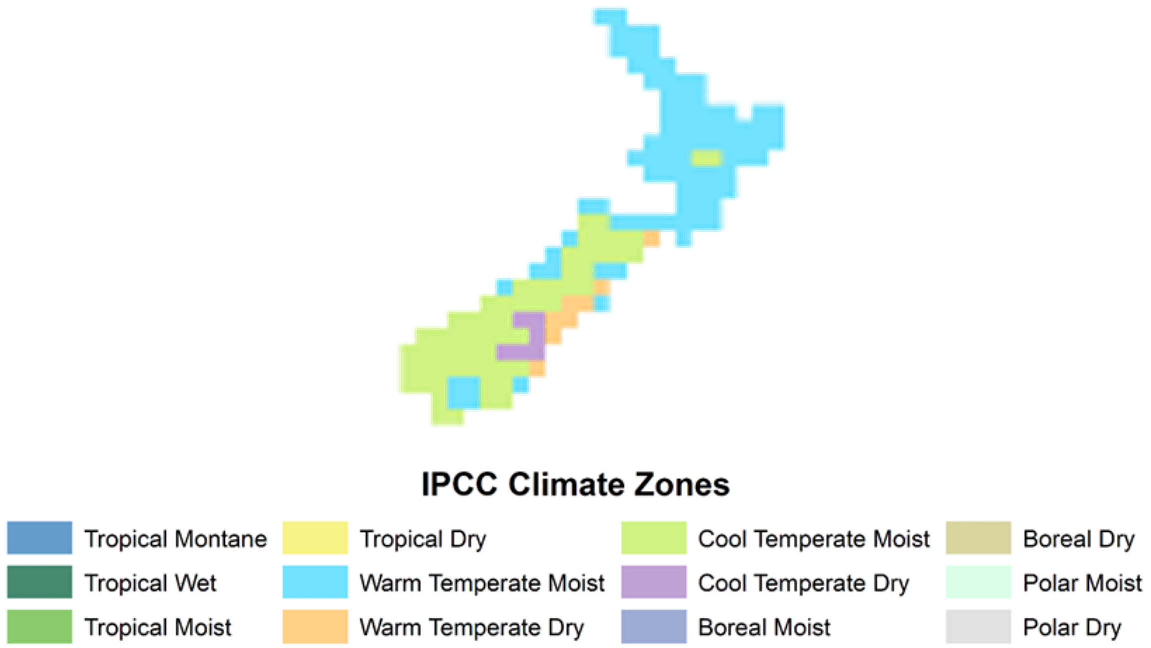


*Table 8: Regional solid storage Methane Conversion Factors (MCF) based on IPCC 2019 refinement*

| Region | Dominant climate zone | Solid Storage MCF |
|---|---|---|
| **Northland Region** | Warm temperate, Moist | 0.04 |
| **Auckland Region** | Warm temperate, Moist | 0.04 |
| **Waikato Region** | Warm temperate, Moist | 0.04 |
| **Bay of Plenty Region** | Warm temperate, Moist | 0.04 |
| **Gisborne Region** | Warm temperate, Moist | 0.04 |
| **Hawke's Bay Region** | Warm temperate, Moist | 0.04 |
| **Taranaki Region** | Warm temperate, Moist | 0.04 |
| **Manawatū-Whanganui Region** | Warm temperate, Moist | 0.04 |
| **Wellington Region** | Warm temperate, Moist | 0.04 |
| **West Coast Region** | Warm temperate, Moist | 0.04 |
| **Canterbury Region** | Warm temperate, Dry | 0.04 |
| **Otago Region** | Cool temperate, Moist **(Revised to Warm temperate, Dry)** | 0.02 **(0.04)** |
| **Southland Region** | Cool temperate, Moist | 0.02 |
| **Tasman Region** | Cool temperate, Moist **(Revised to Warm temperate, Moist)** | 0.02 **(0.04)** |
| **Nelson Region** | Warm temperate, Moist | 0.04 |
| **Marlborough Region** | Cool temperate, Moist **(Revised to Warm temperate, Dry)** | 0.02 **(0.04)** |

*Solid storage nitrogen loss fractions due to volatilisation of $NH_3$ and $NO_x$ ($Frac_{GasMS}$) and leaching of nitrogen ($Frac_{LeachMS}$) from manure management*

23. Table 10.22 in the 2019 refinement suggests default values for nitrogen loss fractions from manure management systems due to volatilisation of $NH_3$ and $NO_x$ ($Frac_{GasMS}$) and leaching of nitrogen ($Frac_{LeachMS}$). The table provides values disaggregated by practice. However, due to limited information on the specific practices used in New Zealand, *solid storage not further defined* was viewed as the most appropriate classification. The Inventory team proposes using the following default values:

a) $Frac_{GasMS} = 0.30$

b) $Frac_{LeachMS} = 0.02$

*Table 9: Extract from Table 10.22 in the 2019 refinement*

| Solid Storage Variation | Dairy Cow $Frac_{GasMS}$ | Dairy Cow $Frac_{LeachMS}$ |
|---|---|---|
| **Covered/compacted** | 0.14 (0.02 - 0.17) | 0 |

| | | |
|---|---|---|
| **Bulking agent addition** | 0.38 (0.06 - 0.46) | 0.02 |
| **Additives** | 0.11 (0.01 - 0.14) | 0.02 |
| **Solid storage not further defined** | 0.30 (0.1-0.4) | 0.02 |

24. Further research could be undertaken in the future to better describe in more detail the solid storage systems used in New Zealand. This could include composting, dry lot, and the variations in table 9.

**Proposed change – seasonal distribution of manure to manure management systems**

25. Luo et al. (2025) also investigated seasonal and regional variation in the use of off-paddock facilities across Fonterra farms. Figure 1 presents a heatmap showing total cow hours spent in off-paddock facilities, excluding time spent in milking sheds.

26. The analysis found seasonal patterns in the use of off-paddock facilities. Usage was highest in winter, lowest in summer, and moderate in spring and autumn. Livestock housing and loafing pads were used most during winter, while feed pads were used evenly throughout the year. Table 10 below shows the seasonal breakdown of time spend on different facilities.

27. There were also notable regional differences. Feed pads were used more extensively in the North Island, while livestock housing was more common in the South Island, particularly during winter. Usage of stand-off loading pads was similar between the two islands.

*Figure 3: Spatiotemporal variation in the proportion of off-paddock facility use: Expressed in percentage of cow hours in off-paddock facilities*

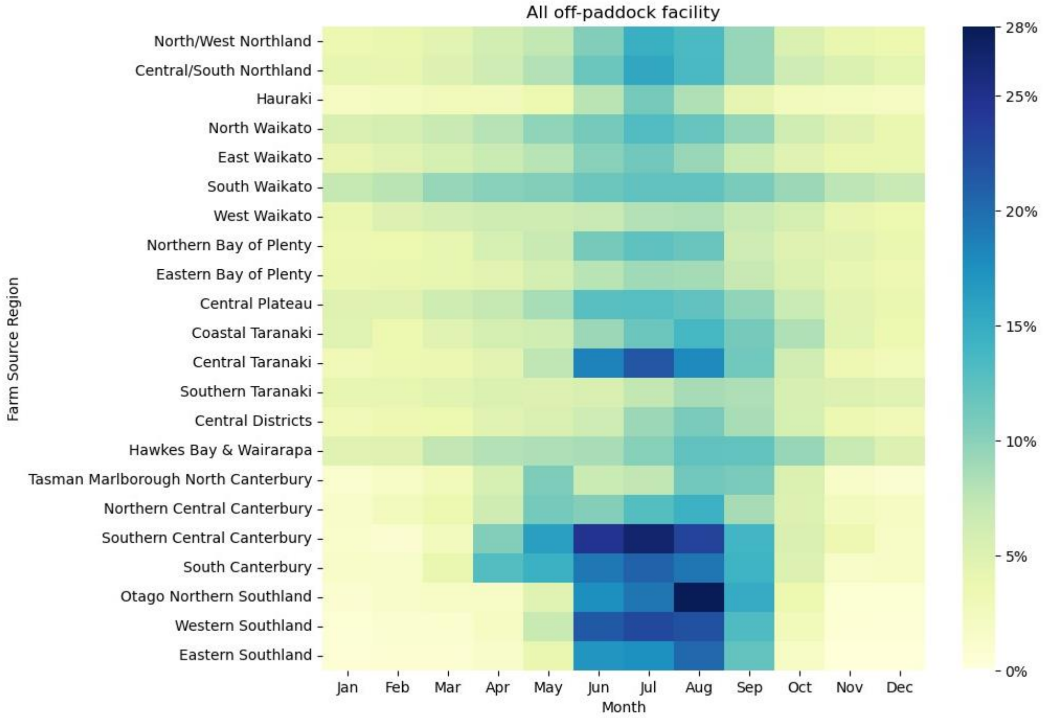


*Table 10: Seasonal breakdown of time spent (and therefore manure collected) on off paddock facilities*

| Facility Type | Annual Usage (%) | Winter (June – August) (%) | Spring (September – November) (%) | Summer (December – February) (%) | Autumn (March – May) (%) |
|---|---|---|---|---|---|
| **All Off-Paddock** | 2.7 | 5.16 | 2.32 | 1.20 | 2.12 |
| **Feed Pads** | 1.54 | 2.00 | 1.60 | 1.04 | 1.56 |
| **Loafing Pads** | 0.30 | 0.88 | 0.24 | 0.00 | 0.08 |
| **Livestock Housing** | 0.85 | 2.28 | 0.52 | 0.16 | 0.48 |

28. The report does not directly recommend using the seasonal or regional disaggregation. However, the Inventory team considers there to be sufficient evidence to support seasonal disaggregation of manure inputs to manure management systems.

29. The Inventory team's proposed approach uses the recommended annual proportions of manure collected in each facility to calculate the total annual manure collected by each facility. These annual totals are then allocated by month using the relative seasonal distribution. This method ensures that seasonal allocation remains consistent with the annual proportions. Table 11 shows the seasonal proportions.

30. For manure collected in milking sheds we are proposing a similar procedure, but using the proportion of annual milk collected in each month to allocate the total annual manure to month.

*Table 11: Seasonal proportion of total annual manure collected on off-paddock facilities (excluding milking sheds)*

| | Winter (June – August) | Spring (September – November) | Summer (December – February) | Autumn (March – May) |
|---|---|---|---|---|
| **Feed pad** | 32% | 26% | 17% | 25% |
| **Stand-off loafing pad** | 73% | 20% | 0% | 7% |
| **Housing** | 66% | 15% | 5% | 14% |

**Effect of proposed changes on emissions**

47. Updating the annual proportions of dairy manure directed to anaerobic lagoons and solid storage is estimated to reduce emissions by approximately 107 kilotonnes of carbon dioxide equivalent ($CO_2$-e, GWP 100 AR5) in 2023. This represents a 0.26% reduction in New Zealand's total agricultural greenhouse gas emissions.

48. Incorporating seasonal allocation slightly increases emissions by around 7 kt $CO_2$-e in 2023. This is less than 0.1% of total agricultural emissions.

49. The net effect of both changes is a total reduction of 100 kt $CO_2$-e

50. Only emissions from mature milking cows are affected by these changes.

51. At a more disaggregated level, the proposed change would change reported emissions from:

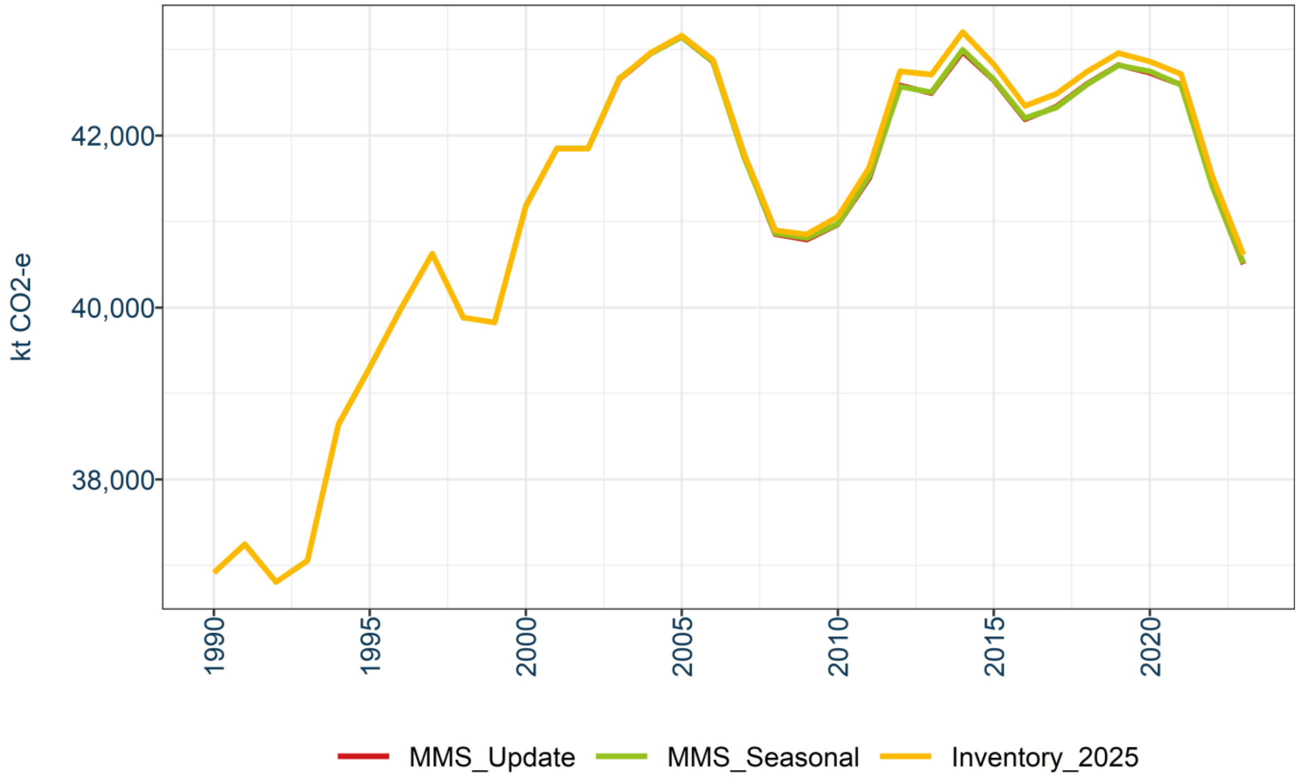
*Table 12: Impact of proposed changes on emissions by reporting category in 2023*

| | Manure management (kt $CO_2$-e) | Agricultural soils (kt $CO_2$-e) |
|---|---|---|
| **Updated annual proportions of dairy manure entering manure management systems** | -99.17 | -7.74 |
| **Seasonal proportions applied** | 17.32 | -10.50 |
| **Total** | -81.85 | -18.24 |

52. Combined this is a 5.1% reduction in manure management emissions from dairy and a 0.8% reduction in agricultural soils emissions from dairy.

53. The main cause of this change is the reduction in mature decomposing in anaerobic conditions. The proportion of manure decomposing in anaerobic lagoons decreased from 8.5% of mature dairy FDM to 7.61% of mature dairy FDM. The 1.5% of mature dairy FDM that decomposes in solid storage has a much lower MCF (0.04) compared to liquid anaerobic storage (MCF = 0.74), significantly reducing methane emissions from that portion.

*Figure 4: Total agricultural emissions before and after proposed changes*



### Opportunities and risks

54. All research carried out via the Greenhouse Gas Inventory Research (GHGIR) Fund is done for the direct purpose of increasing the accuracy of reported emissions. Undertaking this research provides us with the opportunity to increase the accuracy of reported agricultural emissions by adopting the findings of up-to-date and robust research within the inventory model.
55. However, all updates to the agricultural inventory must be suitably robust and defensible to international reviewers. If changes are made which do not adhere to these criteria, then this poses a significant risk to the credibility of the inventory and other policy and international targets which utilise this as a source of information. We have mitigated this risk by commissioning an independent review of the research and by thoroughly testing the logic of the recommended changes in the inventory model.
56. These changes support more realistic modelling of EcoPond's mitigation potential. The changes to the proportion of manure allocated to anaerobic lagoons reduces the target emissions source. The seasonal disaggregation also aligns with the incorporation of EcoPond, as accounting for this technology requires information on accurate timing of effluent treatment.

### Next steps

57. Two options are proposed:

    Option A

    Adopt any or all of the recommended changes to activity data and methodology for calculating emissions from dairy manure management.

    a. updated annual proportions of dairy manure entering manure management systems
    b. default emission factors for solid storage
    c. seasonal allocation of total annual manure collected on structures

    Option B (status quo)

    Continue with the status quo as outlined in the current (version 11) of the methodology document.

58. If the Panel recommends the adoption of Option A, this recommendation will go to the Deputy Director General (Policy and Trade) and Reporting Governance Group for approval to include in the 2026 Inventory.

**Recommendations**

The Greenhouse Gas Inventory Team recommends that the Agricultural Inventory Advisory Panel:

59. **Recommend** the use of the updated annual proportions of dairy manure entering manure management systems, including the use of default emission factors for solid storage.

**Agree**

**Do not agree**

60. **Recommend** the seasonal allocation of total annual manure collected on structures

**Agree**

**Do not agree**

**Approved/ Not Approved/ Approved as Amended**

Gerald Rys
Principal Science Advisor, Office of the Chief Dept Science Adviser
Chair, Agricultural Inventory Advisory Panel

3/2/26

## References

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