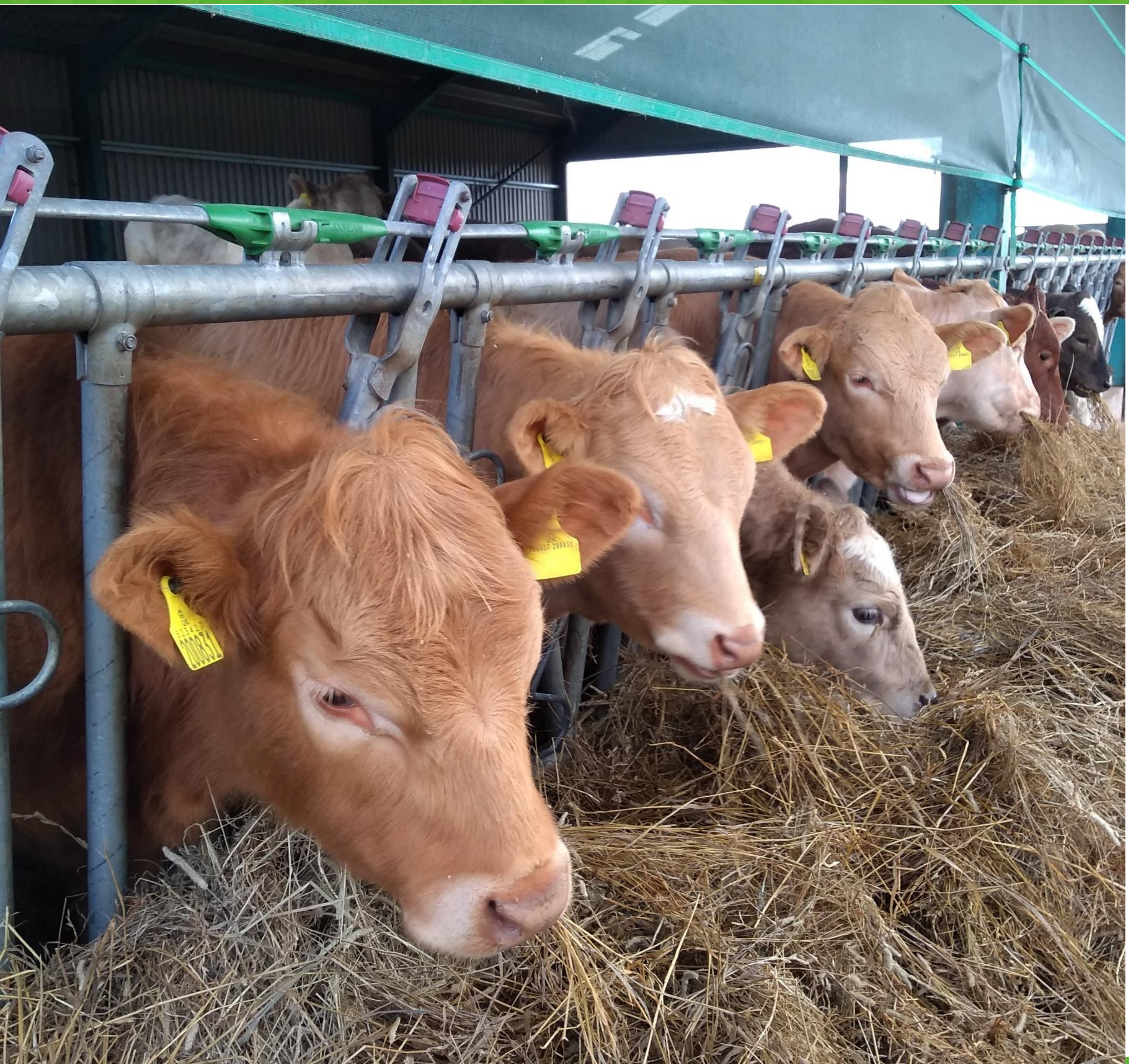


# Estimated Suckler Beef Climate Scheme effect within the National GHG ‘Smart’ Inventory

# Estimated Suckler Beef Climate Scheme effects within the National GHG 'Smart' Inventory

**Andrew Moxey (Pareto Consulting)**
**with**
**Steven Thomson (SRUC)**

**October 2020**

*Photos:*
*SAC Consulting & S Thomson*

*This work was funded by Scottish Government Rural and Environment Science and Analytical Services*

## Key Points

- Beef cattle account for a significant share of Scottish agricultural emissions (>2.6/7.5Mt $CO_2e$)
- Mitigation is possible via improving production efficiency, not just reducing cattle numbers
- Enteric methane dominates by far, but methane and nitrous oxide from manure also important
- To register against emission targets, mitigation effort needs to register in the 'Smart' Inventory
- The Inventory models emissions by cattle breed, 'role' and age plus farm type and management
- Cattle numbers are taken from CTS; management data (e.g. diets, manure handling) from surveys
- Pending more refined analysis using actual Inventory models and data, approximate emission factors and shares can be inferred from available Inventory results
- Such approximations can be used to confirm Inventory responsiveness to proposed metrics
- Changes to rate of calving and on-farm-mortality will register automatically, and will lower reported emissions (but only if accompanied by reductions in the herd size)
- Changes to calving patterns and slaughter ages will also register automatically, and lower reported emissions (but further work is needed on diets interacting with growth rates)
- Methane inhibitors are not currently included in the Inventory, but could be accommodated to register emission reductions (but only if supported by credible evidence, including on usage)
- Similarly, changes to manure storage and disposal (and diets) can be accommodated, but require more detailed and up-to-date Scotland-specific survey data
- Upper-bound registerable mitigation is c.24-39%, but biological, production system and market constraints are binding; achieving half would save c.10-20%, 0.26 – 0.52 Mt $CO_2e$
- Overall emission reductions will depend crucially upon targeted uptake of mitigation actions and on market responses to future trade arrangements

## Acknowledgements

**We would like to acknowledge the support and advice from Steven Anthony (ADAS), Vera Eory (SRUC), Michael Macleod (SRUC) and Adrian Williams (Cranfield University) in generating the evidence presented in this paper.**

# Contents



# List of Tables

# Introduction

1. Beef cattle generate methane (CH4) from both enteric fermentation in their rumen and anaerobic decomposition of volatile solids in their manure. Their manure also emits, both directly and indirectly, nitrous oxide (N2O) as the excreted nitrogen in dung and urine undergoes nitrification and then denitrification.[1]

2. These emissions can be tackled through various mitigation actions, including reducing the number of cattle but also improving production efficiency. In particular, enteric fermentation is influenced by the efficacy of animals turning feed into meat, which can be improved through a combination of breeding selection, good animal health and dietary management to improve the efficiency with which feedstuffs are converted into liveweight gains: enteric methane represents a loss of dietary energy and reducing this loss improves productivity.

3. Similarly, whilst affected by environmental conditions such as temperature and pH, emissions from excreted volatile solids and nitrogen are also influenced by the volume and chemical composition of manure, which is in-turn influenced by the size and breed of an animal but more notably by diet and by how excretions are handled in terms of their storage and disposal.

4. However, the degree to which on-farm mitigation efforts are captured by reported totals of these emissions in the National Inventory, and hence the degree to which they will register against aggregate reduction targets, depends on the level of detail underpinning the Inventory. This matters since the proposed Beef Suckler Climate Scheme seeks to mitigate emissions through changing management practices and altering the structure of the national herd. Whilst this will retain more of the sector's social and economic contributions than if the national herd simply shrank in an *ad hoc* manner, it will only be reflected by Inventory figures if the Inventory is capable of registering such changes. This paper considers the likely responsiveness of the Inventory to proposed Scheme metrics.

# The Smart Inventory

5. Whereas previous versions of the National Inventory used simpler, fixed emission factors (i.e. coefficients) per animal, the 'Smart' inventory calculates emissions more dynamically using a set of models to account better for heterogeneity across different farming systems. Precise details of the assumptions and data used in these models are not readily accessible, but the following summary has been collated from information sourced through various expert contacts and guidance issued by the Intergovernmental Panel on Climate Change (IPCC).

6. Beef (denoted in the Inventory as 'Other cattle')[2] emission totals are estimated by using data on monthly animal numbers from the Cattle Tracing System (CTS) together with estimates of the proportion of animals falling within particular categories defined by a combination of farm type,

[1] Other emissions may also arise from, for example, the production of inputs such as feed, fertilisers and energy used in beef enterprises. However, these emissions are not reported as livestock emissions *per se* in official figures, and indeed may not be included at all if they arise in other countries exporting to the UK/Scotland. This highlights a difference between the coverage and methodology behind national figures and those of on-farm tools (such as AgreCalc), but also the potential for headline domestic totals and targets to give only a partial perspective. Nevertheless, restricting attention here to a narrow perspective is sufficient to illustrate the responsiveness of official national beef emissions to on-farm changes.

[2] Only dairy cows and their replacements are listed explicitly as dairy, meaning that adjustments have had to be made here to exclude dairy-beef calves, using CTS data (see accompanying report).

cattle breed, 'role', age and management. The latter includes the volume and quality of feed used in diets, the location of animals (i.e. housed, yarded, grazed) and how manure is handled, all at different points in the year. Data on diets, on-farm locations and manure handling are drawn from various surveys of farm practices, although these mainly relate only to England (meaning that Scottish-specific conditions are possibly misrepresented) and/or have not all been updated recently.

7. Breed, 'role' and (to a lesser extent) farm type effectively define different farming systems in terms of typical diets and liveweight growth patterns. Robust Farm Types are those used in England[3] rather than Scotland, meaning that LFA grazing is not sub-divided into finer gradations of cattle and sheep specialisms (although the latter could be accommodated if Scottish data were provided).

8. Reported breeds are categorised as Continental, Dairy, Lowland and Upland, although reference is made to a finer sub-categorisation used in the actual models (but emissions vary less across breeds than across different diets).

9. Age is split into 17 different categories, starting with 0 to 3 months and advancing in three-month blocks until 33 to 36 months, but then 36 to 48 and 48 to 60 months, and finally 60 to 240 months and 240 to 300 months. These age splits are used to reflect how capacities for feed intake, energy requirements and growth rates vary as an animal matures, and to allow for the possibility of dietary composition varying over time (e.g. previously grass-fed animals can be finished on concentrates).

10. 'Role' categorises cattle into five types: beef females for slaughter, bulls for breeding, cereal fed bulls, cows, heifers for breeding and steers. This allows for further differentiation between animals in terms of dietary intakes and growth rates.

## Implied emission factors

11. Although emission factors per animal are no longer used *per se*, it is possible to calculate implied emission factors from Smart Inventory results. This cannot be done directly from the published results but is possible from more detailed spreadsheets provided by Inventory compilers.

    Scottish results by farm type and breed are not currently accessible, but some information on emission totals by role and age is available and has been used to calculate the implied emission factors and shares of aggregate emissions shown in Table 1 to

12. Table 4 below. In addition, Table 5 has been compiled specifically in relation to manure-related emissions.

13. It is important to note that the figures presented in these Tables relate to Inventory results for a specific year (2018) with a given distribution of beef production across the different farm type * cattle breed * 'role' * age * management categories - changes to this distribution would alter the implied emission factors and emission shares.

14. Nevertheless, these Tables can be used for some simple "what if" checks of Inventory responsiveness to proposed mitigation actions without access to the full underlying data and models. The results of this approach should be treated as accurate to only a first approximation, sufficient to illustrate the likely magnitude of sensitivity of Inventory totals to Scheme metrics and to

[3] Cereal, Dairy, General Cropping, Horticulture, LFA grazing, Lowland grazing, Mixed, Specialist Pig, Specialist Poultry. NB. Fixed Standard Output coefficients are used to avoid churn in farm type classifications over time.

reveal issues for further exploration, but not offering precise estimates: use of the actual models and data underpinning the Inventory would offer more refined estimates.

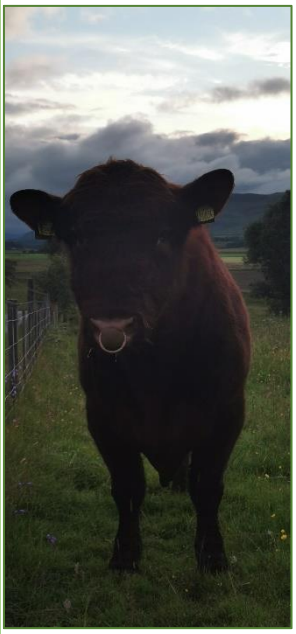
*Table 1: Approximate emission factors (kg CO2e/head/year) by Inventory code and bovine 'role'*

| Inventory Category | 3A1b Enteric CH4 | 3B11b Manure CH4 | 3B21b Direct N2O | 3B25/D21/D22 Indirect N2O | 3D12a/13 Excreta to soil N2O | Total |
|---|---|---|---|---|---|---|
| **Beef female for slaughter** | 1,393 | 204 | 176 | 44 | 76 | **1,893** |
| **Bulls for breeding** | 1,675 | 273 | 172 | 64 | 110 | **2,294** |
| **Cereal fed bull** | 1,411 | 292 | 282 | 59 | 64 | **2,108** |
| **Cows** | 2,161 | 349 | 172 | 67 | 114 | **2,863** |
| **Heifers for breeding** | 1,369 | 205 | 154 | 45 | 77 | **1,850** |
| **Steers** | 1,421 | 209 | 183 | 46 | 77 | **1,936** |

***Source:*** *derived from 'Coded model output' tab of 'Ag_Inventory_submission_1970-2018v2' supplied by Rothamsted Research via SG, and compared with generic estimates available in the literature and estimates similarly derived from data supplied by ADAS via SG and SRUC.*
***NB.*** *these figures exclude other emission categories, notably those associated with fertiliser applications to produce feed or on-farm energy use, which are logged elsewhere in the Inventory. This contrasts with farm-level carbon tools (e.g. AgreCalc) which typically include broader emissions, but is sufficient to explore responsiveness of the Inventory to proposed Suckler Beef Climate Scheme metrics.*

*Table 2: Approximate emissions (kg CO2e/head/year), by age and bovine 'role'*

| Age | Beef female for slaughter | Bulls for breeding | Cereal fed bull | Cows | Heifers for breeding | Steers |
|---|---|---|---|---|---|---|
| **0-3** | 832 | 835 | 1,461 | n/a | 731 | 1,003 |
| **3-6** | 1,519 | 1,367 | 2,079 | n/a | 1,214 | 1,782 |
| **6-9** | 2,350 | 1,995 | 2,508 | n/a | 1,914 | 2,305 |
| **9-12** | 2,207 | 2,222 | 2,204 | n/a | 2,008 | 2,144 |
| **12-15** | 1,964 | 2,256 | 2,112 | n/a | 1,886 | 1,986 |
| **15-18** | 2,017 | 2,486 | 2,114 | 2,853 | 2,015 | 2,024 |
| **18-21** | 2,107 | 2,612 | 2,115 | 2,996 | 2,179 | 2,050 |
| **21-24** | 1,974 | 2,548 | 2,122 | 2,940 | 2,018 | 1,981 |
| **24-27** | 1,855 | 2,491 | 2,131 | 2,697 | 1,927 | 1,919 |
| **27-30** | 1,910 | 2,580 | 2,139 | 2,814 | 2,076 | 1,980 |
| **30-33** | 1,995 | 2,605 | 2,132 | 2,985 | 2,190 | 2,016 |
| **33-36** | 2,040 | 2,598 | 2,144 | 2,926 | 2,063 | 1,971 |
| **36-48** | n/a | 2,561 | 2,154 | 2,788 | n/a | 1,973 |
| **48-60** | n/a | 2,553 | n/a | 2,841 | n/a | n/a |
| **60-240** | n/a | 2,612 | n/a | 2,867 | n/a | n/a |
| **240-300** | n/a | 2,496 | n/a | 2,804 | n/a | n/a |
| **Overall** | **1,893** | **2,294** | **2,108** | **2,863** | **1,850** | **1,936** |



***Source:*** *derived from data supplied by ADAS via SG and SRUC. Average emissions increase with age, but fluctuate - presumably due to underlying variation in the prevalence of different breeds and management systems within each age group (as per caveat noted in para 13).*

*Table 3: Approximate shares (%) of total beef[4] emissions, by emission category and bovine 'role'*

| Inventory Category | 3A1b Enteric CH4 | 3B11b Manure CH4 | 3B21b Direct N2O | 3B25/D21/D22 Indirect N2O | 3D12a/13 Excreta to soil N2O | Total |
|---|---|---|---|---|---|---|
| **Beef female for slaughter** | 18% | 17% | 22% | 18% | 18% | **18%** |
| **Bulls for breeding** | 3% | 3% | 3% | 3% | 3% | **3%** |
| **Cereal fed bull** | 2% | 2% | 3% | 2% | 1% | **2%** |
| **Cows** | 48% | 50% | 37% | 46% | 47% | **47%** |
| **Heifers for breeding** | 10% | 10% | 11% | 10% | 11% | **10%** |
| **Steers** | 20% | 19% | 25% | 20% | 20% | **20%** |
| **Mt CO2e** | **1.93** | **0.30** | **0.20** | **0.06** | **0.10** | **2.59** |
| **% of total beef emissions (2.59Mt CO2e)** | **(75%)** | **(12%)** | **(8%)** | **(2%)** | **(4%)** | **(100%)** |

***Source:*** *as Table 1, weighted by livestock headcounts (excluding calves from the dairy herd), with aggregate emission totals cross-checked against figures reported in the 'Scotland by source' tab of published National Inventory at* ***http://uk-air.defra.gov.uk/reports/cat09/2006160834_DA_GHGI_1990-2018_v01-04.xlsm***

*Table 4: Approximate shares (%) of total beef emissions, by age structure and bovine 'role'*

| Age | Beef female for slaughter | Bulls for breeding | Cereal fed bull | Cows | Heifers for breeding | Steers | Total |
|---|---|---|---|---|---|---|---|
| **0-3** | 1% | 0% | 0% | 0% | 0% | 1% | **2%** |
| **3-6** | 2% | 0% | 0% | 0% | 1% | 3% | **6%** |
| **6-9** | 3% | 0% | 0% | 0% | 1% | 3% | **8%** |
| **9-12** | 3% | 0% | 0% | 0% | 1% | 3% | **7%** |
| **12-15** | 2% | 0% | 0% | 0% | 1% | 2% | **6%** |
| **15-18** | 2% | 0% | 0% | 0% | 1% | 2% | **6%** |
| **18-21** | 2% | 0% | 0% | 0% | 1% | 2% | **5%** |
| **21-24** | 2% | 0% | 0% | 0% | 1% | 1% | **4%** |
| **24-27** | 1% | 0% | 0% | 0% | 1% | 1% | **3%** |
| **27-30** | 1% | 0% | 0% | 1% | 1% | 0% | **2%** |
| **30-33** | 0% | 0% | 0% | 1% | 1% | 0% | **2%** |
| **33-36** | 0% | 0% | 0% | 1% | 1% | 0% | **2%** |
| **36-48** | 0% | 1% | 0% | 8% | 0% | 0% | **9%** |
| **48-60** | 0% | 0% | 0% | 6% | 0% | 0% | **6%** |
| **60-240** | 0% | 1% | 0% | 29% | 0% | 0% | **31%** |
| **240-300** | 0% | 0% | 0% | 0% | 0% | 0% | **0%** |
| **Total** | **18%** | **3%** | **2%** | **47%** | **10%** | **20%** | **100%** |

***Source:*** *as Table 1, weighted by monthly livestock headcounts (excluding calves from the dairy herd) and summed across Inventory emission categories*

[4] Excluding calves from the dairy herd reared for slaughter as beef animals. Including dairy-beef calves raises the overall total emissions to 3.03 Mt CO2e, lowers the relative emission share of cows to 40% (because dairy cows appear elsewhere in the Inventory) and raises the relative shares of beef females for slaughter (to 19%), cereal fed bulls (to 5%) and steers (to 24%).

*Table 5: Approximate excreted VS and N plus approximate direct emission factors applied to these*

| VS excreted (kg/hd/yr) 661kg– 1,064kg | | | |
|---|---|---|---|
| N excreted (kg/hd/yr) | 38kg – 57kg | Manure CH4 degradability | 18% |
| CH4 Managed manure conversion | 14% | CH4 Unmanaged (grazing) conversion | 1% |
| N2O-N Spread slurry | <1% | N2O-N Unmanaged (grazing) conversion | <0.5% |
| N2O-N Spread FYM | <0.5% | | |

**Source:** *derived from information provided by ADAS via SRUC*

## Smart Inventory responsiveness to proposed Scheme metrics

25. Table 3 suggests aggregate emissions from Scottish suckler beef in 2018 were approximately 2.6Mt of carbon dioxide equivalent (CO2e), out of the Scottish agricultural total of 7.5Mt CO2e. Enteric methane (Inventory Code 3A1b) dominates at 1.9Mt CO2e, with manure methane (3B11b) contributing 0.3Mt CO2e, direct manure nitrous oxide (3B21b) 0.2Mt CO2e, with a further 0.06 Mt CO2e of indirect N2O (3B25/3D21/3D22) and 0.10 Mt CO2e of N2O from soils receiving spread manure or dung and urine via grazing (3D12a & 3D13).[5]

26. Using the Tabular estimates presented above, the following summaries are offered of how types of mitigation action identified within the Suckler Beef Climate Scheme could be reflected in the Inventory.

### *Registered calving rates*

27. Analysis of CTS data (see accompanying report) indicates a **national registered calving rate[6] of around 80% for the beef herd**. This represents a significant overhead burden in that unproductive[7] cows contribute to overall emissions without contributing to actual beef production, thereby unnecessarily increasing both emissions-intensity and aggregate emissions.

28. Reducing the number of unproductive cows by culling would (all other things being equal)[8] reduce emissions without affecting beef production. However, reducing the prevalence of unproductive cows through better management would increase the number of calves born and (all other things being equal) increase overall emissions even whilst reducing the emission-intensity of beef

[5] Published figures do not separate-out beef emissions within these last two categories (given as 0.18Mt and 0.28Mt CO2e respectively for all livestock in the Table 3 cross-check source), but estimates can be derived from the 'Coded model output' tab of the 'Ag_Inventory_submission_1970-2018v2' spreadsheet supplied. As noted in Footnote 1, beef shares of other emissions, notably energy use and fertiliser applications for the production of feed are not reported in the Inventory under livestock emissions and hence have not been considered here, meaning that the total of 2.6Mt CO2e is an under-estimate, albeit consistent with how the Inventory presents the sectoral breakdown.
[6] Calves born dead or dying before being registered are not recorded – hence the true calving rate is unknown.
[7] Including those failing to conceive but also those losing calves during pregnancy or prior to calf registration.
[8] In reality, other production adjustments would be expected to accompany such changes – meaning that overall effects on emissions could be higher or lower.

produced. In both cases, the National Inventory would reflect the changes automatically through the CTS headcount data.

29. For example, Table 3 shows that **beef cows are responsible for approximately 47% of beef emissions and heifers for breeding 10%,** meaning that removal of the 20% of unproductive capacity (i.e. removing all unproductive cows and associated breeding heifer replacements) would (all other things being equal) **deliver a reduction in total emissions of around 11%, or 0.30 Mt CO2e**. By contrast, raising the calving rate to 100% whilst keeping the same productive capacity would increase the number of cereal fed bulls, beef females for slaughter and steers by 20%, implying an increase in overall emissions of 8% or 0.21Mt CO2e (highlighting why targeted herd reduction measures are likely to be needed).

### *On-farm mortality rates*

30. Analysis of CTS data by SRUC indicates that the overall **on-farm mortality rate between registration of a calf and three years of age is approximately 6%.** As with directly unproductive cows, the loss of an animal before slaughter means that the overhead burden of a cow is incurred without any accompanying beef production, along with emissions over the (short) lifetime of the prematurely-dying offspring, inflating the emission-intensity of beef that is produced.

31. If on farm-mortality rates were lowered, the number of breeding cows and hence overhead emissions required to produce a given volume of beef could be reduced. For example (all other things being equal) a **6% decline in the number of cows and associated breeding heifers would generate a 3% or 0.09Mt CO2e reduction in emissions**. This would be automatically detected by the Inventory through changes in the CTS headcount.

32. However, **as with calving rates, if improved mortality rates are achieved without reducing the breeding herd, emissions will increase.** For example, 6% more animals successfully finished for slaughter implies an increase in emissions of approximately 2% or 0.06 Mt CO2e. Again, this would be automatically detected by the Inventory.

### *Calving intervals and age of first calving*

33. Although not as significant an overhead emissions burden as that of unproductive cows, longer calving intervals also represent an avoidable overhead. The models underpinning the Inventory do not explicitly accommodate changing calving intervals since the CTS data used by the Inventory are restricted only to headcounts. However, to the extent that shorter calving intervals would alter the age structure of the herd, effects would be accommodated implicitly.

34. Moreover, explicit inclusion of the headcount of 'heifers for breeding' split by age category means that on-farm efforts to calve heifers at a younger age would also automatically be captured by the Inventory. For example, Table 4 suggests that **eliminating breeding heifers over the age 24 months by bringing calving ages forward would (all other things being equal) yield savings of 4% or 0.10Mt CO2e.**

### *Faster finishing*

35. Keeping animals beyond the age that they reach slaughter weight and/or taking longer than necessary to reach slaughter weight incurs unnecessary emissions. Fortunately, selecting faster-growing animals through breeding/genetics, maintaining good animal health, matching nutrition to energy requirements and improving the digestibility of feed can all accelerate growth rates to achieve target slaughter weights at a younger age.

For example,

36. Table 4 suggests that **prime cattle slaughtered over the age of 24 months account for 3% of total beef emissions.** If these animals were instead all finished by 24 months, these emissions would (all other things being equal) be avoided, **saving 3% or 0.1Mt CO2e. Lowering the slaughter age to 21 months would yield further savings of 3% or 0.1mt CO2e.** Such changes would be reflected automatically by the Inventory through the CTS headcount.

37. However, as currently configured, the Inventory interprets earlier slaughtering simply as slaughter at an earlier point (and lower liveweight) on the growth curve used for a given animal (which will depend on 'role', breed, farm type etc.). This means that the emission effects of varying the diet to achieve the same slaughter weight earlier are not accounted for, probably exaggerating net emission savings. Researchers responsible for compiling the Inventory are aware of this limitation and would welcome an opportunity to improve how diets, growth curves, live slaughter weights and killing-out percentages are represented; SRUC could contribute to this.

### *Manure generation, storage and disposal*

38. The Inventory methodology distinguishes between livestock waste excreted directly to fields via grazing and as purposively collected and managed manure. Further distinctions are made between slurry and farmyard manure, and between waste generated in housing or yards and indeed on specific techniques for storage (e.g. covered slurry pits) and spreading (e.g. daily, injected etc.).

39. These differences are parameterised as the fraction of volatile solids or nitrogen actually converted into emissions under different routes, and used in combination with information on the proportion of animals being managed under each of the different systems at different times during the year. This ensures that Inventory results can reflect shifts in the volume and composition of livestock waste arising from changing diets and/or shifts in how waste is handled. For example, Table 5 shows that methane emissions from grazing are lower than from managed manure.

40. However, given the dominance of enteric methane in total beef emissions, mitigation of emissions from manure can deliver only smaller absolute reductions. Moreover, registering effects in the Inventory requires information on farm practices, which is currently somewhat dated and/or England-centric. This reinforces the need for up-to-date and accurate Scottish-specific information on how animals are being managed.

### *Methane inhibitors*

41. On-going research on a range of methane inhibitors suggests that they may reduce enteric emissions by perhaps up to 20% per head for a given volume and quality of feed intake.[9] Given the dominance of enteric methane in total beef emissions, **high uptake of effective inhibitors offers potentially significant savings. For example, universal uptake of an inhibitor lowering per head emissions of enteric methane by 20% would lower overall beef emissions by around 15% or 0.39Mt CO2e.**

42. As a yet-to-be-implemented technology, methane inhibitors are not currently included in the Inventory. However, provided that the IPCC accepts them as credible, they can be accommodated relatively easily either formally through a reworking of the underpinning dietary models or more simply as an *ex post* adjustment to figures in Table 1. In either case, the determinant of on-the-

[9] Although the persistence of any savings may be dependent on whether the rumen microflora adapts to partially or wholly reverse methane suppression.

ground adoption being reflected in the Inventory will actually be the availability of information on the proportion of animals receiving the inhibitor, in what dosage and for what duration.

## Discussion and conclusions

43. The analysis presented above confirms that most of the CTS-metrics proposed under the Beef Suckler Climate Scheme are accommodated within the existing 'Smart' Inventory methodology. This is because most of the metrics relate to herd size and structure, which are captured automatically through the monthly CTS headcounts already used by the Inventory. As such, uptake of Scheme actions would register against emission reduction targets.

44. Other mitigation actions not summarised by CTS-metrics are also within-scope of the Inventory, but are reliant upon up-to-date and accurate data being provided to describe the distribution of management practices (e.g. diets, time spent housed, use of slurry injection) across different categories of Scottish cattle. This is not currently the case, but researchers responsible for compiling the Inventory are keen to improve how Scottish practices are represented within it.[10] Scottish-specific information could be derived from bespoke surveys (either *ad hoc* or perhaps through a network of 'sentinel' farms) and/or from monitoring of Scheme participants.

45. The emission effects presented here are initial estimates and could (indeed should) be refined using the actual models and data underlying the Inventory (which is itself an imperfect, simplified representation of actual emissions) and/or embedded within farm-level carbon tools. However, they are **sufficient to indicate an upper-bound to the likely order of magnitude of registered emission changes in the Inventory arising from the proposed Scheme**.[11]

46. For example, if it is assumed that all mitigation effects considered here are simply additive and the breeding herd is reduced, **the overall upper-bound for registered mitigation potential is perhaps 24% without methane inhibitors, 39% with them** (**Table 6**).

47. More **realistically, given overlaps between separate mitigation options, the actual technical upper-bound will be lower.** For example, higher calving rates allowing for a reduction in cow numbers will remove some of the benefits of methane inhibitors. **More formal modelling of options' interactions might reveal other overlaps (or indeed synergies), lowering the technical potential to perhaps 20% to 30%.**

48. However, more importantly, **achieving the technical upper bound is impractical given binding biological and market constraints.** That is, whilst the Inventory could register such changes, actual Scheme effects are likely to be less. For example, sustained 100% calving rates and 0% on-farm mortality rates are simply not possible given factors beyond farmers' control, production systems are diverse and complex such that changes to one element (e.g. calving period, feed intensity) can negatively affect other elements (e.g. mortality rates, biodiversity), consistent abattoir throughput over time is not compatible with uniform finishing ages for calves born in a

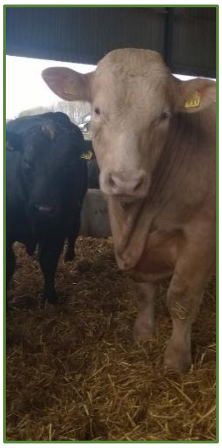
[10] Pasture management has not been considered here, but (at least in principle) could be addressed through Scotland-specific data on how grass and fodder is produced.

[11] As noted in Footnote 1, differences in coverage and methodology (but also degree of aggregation) mean that Inventory estimates cannot be compared directly with those produced by farm-level carbon tools, although the general pattern of reported effects is similar (see accompanying AgreCalc results). It should also be noted that most farm-level carbon tools have yet to be updated to reflect the methodological changes that accompanied introduction of the 'Smart' Inventory, although this is not expected to make a significant difference to the magnitude of estimated farm-level effects.

narrow window dictated by the timing of spring grass, **and new technologies such as methane inhibitors are as-yet still unproven. Similarly, necessary changes to production systems in terms of skills, infrastructure, management practices and herd structures will take time.**

*Table 6: Approximate emission savings (Mt CO2e), by mitigation option[12]*

| Mitigation option | Upper-bound | | 50% achievement* | |
|---|---|---|---|---|
| | % | Mt CO2e | % | Mt CO2e |
| **Calving rate** | 11.4% | 0.30 | 5.7% | 0.15 |
| **On-farm mortality** | 3.4% | 0.09 | 1.7% | 0.03 |
| **Younger calving age** | 3.5% | 0.09 | 1.8% | 0.05 |
| **Faster finishing (24m)** | 3.0% | 0.08 | 1.5% | 0.04 |
| **+ Faster finishing (21m)** | 3.1% | 0.08 | 1.6% | 0.04 |
| **Sub-total** | 24.4% | 0.63 | 12.2% | 0.32 |
| **Methane inhibitors** | 14.9% | 0.39 | 7.4% | 0.19 |
| **Total‡** | **39.3%** | **1.02** | **19.7%** | **0.51** |



*‡ summed for simplicity, but unlikely to be simply additive in practice.*
** if half of each upper-bound were achieved, as an example*

49. Moreover, as analysis of CTS data shows (see accompanying Thomson, et al 2020 report), **the distribution of current performance against proposed metrics is very uneven across farms**. Whilst this does provide evidence of the scope for improvement it also highlights that **targeting of support will be needed to achieve emission reductions. For example, enrolling farms already achieving high calving rates would reward existing good practice but not deliver further emission savings**.

50. Similarly, domestic production would be expected to respond to changing trade arrangements after the end of the EU-exit transition period. For example, given that the UK is a net importer of beef (but Scotland a net exporter), it is possible that UK-imports will fall and Scottish production will rise to help fill the gap, thereby at least partially counteracting efficiency savings (yet if domestic production has a lower emissions-intensity than imported beef, the net effect on global emissions would be positive, just not registered in our National Inventory).

51. Achieving around half of the upper-bound potential would deliver approximately 10% to 20%, 0.26 to 0.52Mt CO2e, of savings registered against National Inventory emission reduction targets.

---

[12] As noted in Footnote 1, these figures exclude other emissions associated with livestock, including those arising from feed production, energy use and land use change. Although not all will necessarily be incurred within Scotland (e.g. feed can be imported), these amount to approximately 0.7mt CO2e and would also be expected to decline as a result of the mitigation activities considered here. For example, removing unproductive cows would reduce feed demand. In addition, other mitigation activities, such as improved fertiliser management, would deliver emission savings in the Inventory – provided that changes in fertiliser practice were captured by Scottish-specific data. However, quantification of possible savings is beyond the scope of this paper.

SRUC

**At the heart of the natural economy**