Retrospective Assessment of Greenhouse Gas Emissions from the Beef Sector in Greece and Potential Mitigation Scenarios

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Supplementary Information related to Equation 4a and Gross Energy (GE) calculation for methane emission estimations from enteric fermentation using Tier 2 inventory.

Equation 4a:

According to the IPCC guidelines (2006, 2019), the daily GE intake is calculated based on an animal's net energy (NE) requirement. The NE requirement of an animal is the sum of the requirements that an animal needs to support each physiological function (i.e., maintenance, activity, growth, lactation, pregnancy, work, etc.). GE intake for beef cattle was calculated using the following equation, following the guidelines of the IPCC:

$$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_p}{REM}\right) + \left(\frac{NE_g}{REG}\right)}{DE} \right] \text{ (Equation 4a)}$$

where:

GE = gross energy (MJ·day^{-1})

NE_m = net energy required by the animal for maintenance (MJ day^{-1})

NE_a = net energy for animal activity (MJ·day^{-1})

NE_l = net energy for lactation (MJ·day^{-1})

NE_p = net energy required for pregnancy (MJ·day^{-1})

REM = ratio of net energy available in a diet for maintenance to digestible energy

NE_g = net energy needed for growth (MJ·day^{-1})

REG = ratio of net energy available for growth in a diet to digestible energy consumed

DE = digestibility of feed expressed as a fraction of gross energy

The calculations did not consider energy related to draught power or wool production as the examined situation did not involve animals used for work (draught power) or the animals did not produce wool.

I. Net energy for maintenance (NE_m)

NE_m is the net energy required for maintenance related to the amount of energy needed to keep the animal in equilibrium, where body energy is neither gained nor lost. The equation (I) was used for the calculation of net energy for maintenance.

$$NE_m = Cfi \times (Weight)^{0.75} \quad \text{(I)}$$

where:
NE_m= Net energy required by the animal for maintenance (MJ· day^{-1}),
Cfi= Coefficients for calculating NE_m (MJ day^{-1}kg^{-1}) which varies for each animal category,
The Cfi was considered 0.386 for mature cows, 0.370 for bulls, and 0.322 for growing cattle (IPCC, 2019).

II. Net energy for activity (NE_a)

NE_a is the net energy required for animal activity (i.e., to obtain food, water, and shelter). Equation (II) was used for estimating NE_a.

$$NE_a = C_a \times NE_m \qquad \text{(II)}$$

where:
NE_a=net energy for animal activity (MJ·day^{-1})
C_a = activity coefficient corresponding to the animal's feeding situation
NE_m= net energy required by the animal for maintenance (MJ·day^{-1})

Activity coefficients were considered as follows: C_a= 0 for stall-feed (intensive system) = 0; C_a= 0.17 for animals fed in pasture.

III. Net energy for growth (NE_g)

NEg is the net energy needed for growth (i.e., weight gain). Its estimation is based on equation (III). According to the IPCC, constants for conversion from calories to joules, and live to shrunk and empty body weight have been incorporated into the equation.

$$NE_g = 22.02 * \left(\frac{BW}{C \times MW}\right)^{0.75} \times WG)^{1.097} \qquad \text{(III)}$$

where:
NE_g = net energy needed for growth (MJ·day^{-1})
BW = the average live weight of the animal in the population (kg)
C = coefficient with a value of 0.8 for females, 1.0 for castrate, and 1.2 for bulls (IPCC, 2019)
MW = the mature live body weight of an adult animal in moderate body condition (kg)
WG = the average daily weight gain of the animals in the population (kg·day^{-1})

Based on national data (Nikolaou et al.,2020), castrated animals are not produced at the country level, and the average BW (equal to mature body weight) for adult male and female animals was 702.2 Kg and 475.6 Kg, respectively. Replacing animals were considered with an average BW in the population of 237.8 Kg and 351.1 Kg, respectively, and their respective MW equal to those of adult animals. Regarding fattening animals, BW in the population was 356.7 Kg and 527.7 Kg for female and male animals, respectively, and their respective MW were equal to those of adult animals. An average daily weight gain of 800 g and 900 g for female and male fattening animals, respectively, was considered.

IV. Net energy for lactation (NE_l)

NE_l is the net energy required for lactation. It is expressed as the function of the amount of milk produced and its fat content is expressed as a percentage of milk.

$$NE_l = Milk \times (1.47 + 0.40 \times Fat) \qquad \text{(IV)}$$

where:
NE_l= net energy for lactation (MJ·day^{-1})
Milk = amount of milk produced (kg·day^{-1})
Fat = Fat content of milk (%)

For beef breeds an average milk production of 0.8 kg /day with 4% fat content was considered (FAO, 2018)

V. Net energy for pregnancy (NE_p)

NE_p is the energy needed for pregnancy. For cattle, according to the IPCC (2006, 2019), the total energy requirements for pregnancy for a 281-day gestation period averaged over an entire year are computed using equation (V).

$$NE_p = C_{pregnancy} \times NE_m \qquad \text{(V)}$$

where:
NE_p = net energy for pregnancy (MJ·day^{-1})
$C_{pregnancy}$ = Pregnancy coefficient (0.10 for cattle)
NE_m = net energy required by the animal for maintenance (MJ·day^{-1}; derived from equation I)

VI. Ratio of net energy available in diet for maintenance to digestible energy consumed (REM)
REM is estimated considering the gross energy and was computed using equation (VI) (IPCC, 2019).

$$\mathrm{REM} = \left[1.123 - (4.092 \times 10^{-3} \times \mathrm{DE\%}) + \{1.126 \times 10^{-5} \times (\mathrm{DE\%})^2\} - \left(\frac{25.4}{\mathrm{DE\%}}\right)\right] \quad \text{(VI)}$$

where:
DE% = digestible energy expressed as a percentage of gross energy

According to the IPCC recommendations (2006, 2019), DE (%) has specific ranges according to the implemented diet system. Therefore, based on the examined systems in the present study (intensive and semi-extensive), the DE (%) parameter was considered as follows: DE = 62% for those animals that reared under extensive systems (graze at pasture), DE = 66.5% (average of the range 62%-71%) for those animals that reared under semi-extensive systems (graze at pasture and concentrated feeds or silage are offered) and DE = 72% for animals that reared intensively (mainly concentrated feeds/grains and a low proportion of forage).

VII. Ratio of net energy available for growth in a diet to digestible energy consumed (REG)
REG for cattle was estimated using equation (VII) (IPCC, 2019):

$$\mathrm{REG} = \left[\{1.164 - (5.160 \times 10^{-3}) \times \mathrm{DE\%}\} + \{(1.308 \times 10^{-5}) \times (\mathrm{DE\%})^2\} - \left\{\frac{37.4}{\mathrm{DE\%}}\right\}\right] \quad \text{(VII)}$$

where:
DE% = digestible energy expressed as a percentage of gross energy

DE (%) values were set as previously described in the case of REM.

References

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