OVERSEER® Technical Manual

Technical Manual for the description of the OVERSEER® Nutrient Budgets engine

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Animal metabolisable energy requirements

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Preface

OVERSEER® Nutrient Budgets

OVERSEER® Nutrient Budgets (OVERSEER) is a strategic management tool that supports optimal nutrient use on farm for increased profitability and managing within environmental limits.

OVERSEER provides users with information to examine the impact of nutrient use and flows within a farm and off-farm losses of nutrients and greenhouse gases. An OVERSEER nutrient budget takes into account inputs and outputs and the key internal recycling of nutrients around the farm.

See the OVERSEER website for more detailed information: http://www.overseer.org.nz

This technical manual

OVERSEER is made up of a user interface and an engine. These two components work together to enable users to generate nutrient budget reports. The Technical Manual provides details of the calculation methods used in the OVERSEER engine.

The OVERSEER engine is based on extensive published scientific research. Technical information about the model's development and use can be found in a growing number of conference proceedings and peer-reviewed papers. Given the ongoing upgrades many of the earlier papers no longer reflect the current version.

The Technical Manual chapters provide detailed descriptions of the methods used in the OVERSEER engine's main sub-models. The Technical Manual sets out the underlying principles and sources of data used to build the model engine. It is a description of the model as implemented, and hence references may not now be the most appropriate or cover the range of data of information currently available, or may not necessarily be the most up to date. If the source of some information and/or assumptions is not known or could not be found, this is acknowledged.

The chapters will continually be updated to reflect the current version.

If readers have feedback or further technical information that they consider could contribute to the future development of the model, please provide feedback via the website http://www.overseer.org.nz.

Scientific contribution to model development:

OVERSEER is a farm systems model covering a wide range of science disciplines. Since the model's inception, a large number of researchers from many disciplines and organisations have contributed to its development.

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Animal metabolisable energy requirements

1. Introduction

1.1. Background

This report documents the methods for calculating animal metabolisable energy (ME) requirements (ME requirement sub-model) within the OVERSEER® engine. Animal ME requirements are used to estimate animal pasture intake when animal data is entered using the stock reconciliation input.

A key requirement of the OVERSEER model is estimation of both DM and nutrient intake. The initial model was based on stock units (SU), which is a measure of annual intake. Early surveys indicated that SU's were not always calculated properly to take into account differences in animal productivity, duration animals were on the property, or the effect of imported supplements. Thus total SU's were not always estimated reliably, particularly under high production systems or trading systems. A method was added to calculate stock units based on a metabolisable energy sub-model. This was fortuitous, as it allowed OVERSEER to expand easily to a monthly model, to incorporate greenhouse gas emissions using methods similar to those used in the New Zealand greenhouse gas emissions national inventory (Ministry of the Environment 2011), and to adopt the revised stock unit system (RSU, Woodford and Nicol, 2004).

The relationship between chapters of the technical manual and animal ME requirements is shown schematically in Figure 1. Thus, this document should be read in conjunction with other chapters. In particular, calculation of animal ME requirements are dependent on estimation of animal properties, and the animal model which sets up parameters for use in the ME requirement sub-model .

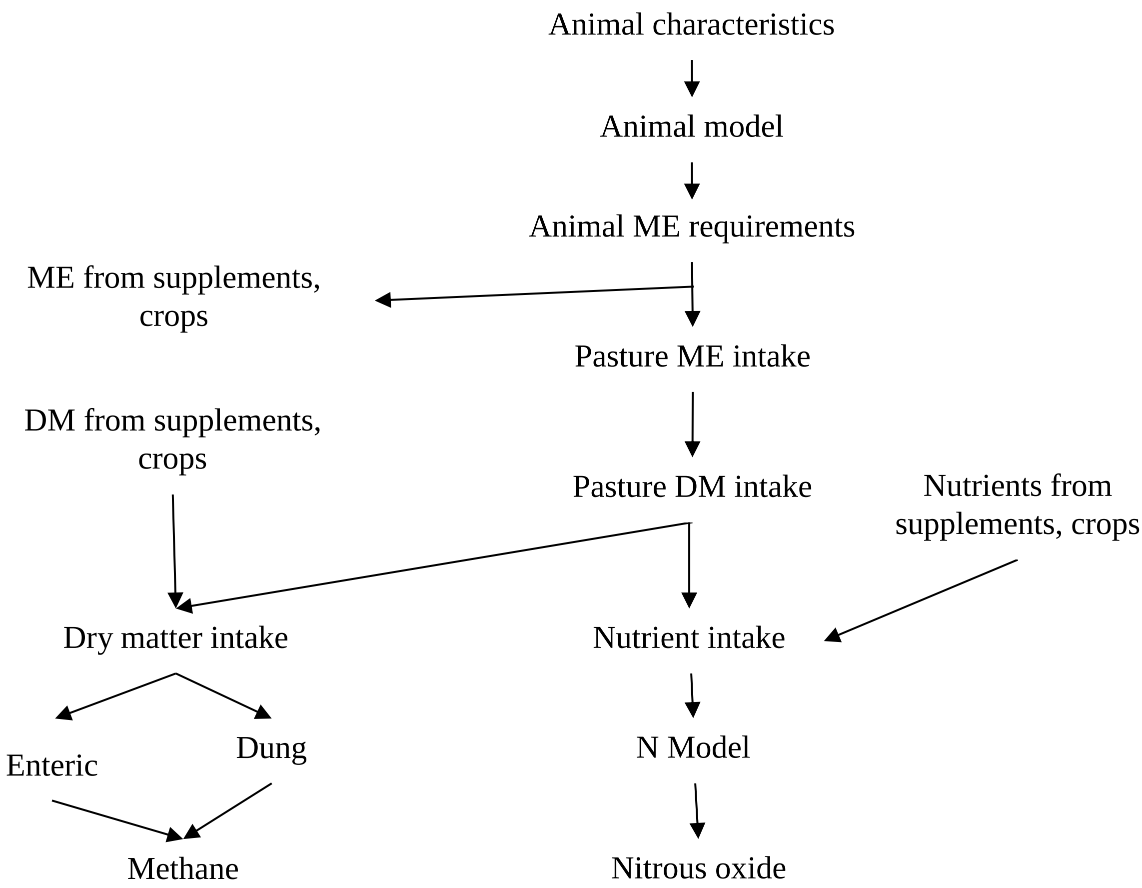

Figure 1. Relationship between sections within the technical manual and estimation of animal ME requirements via a metabolisable energy sub-model.

For dairy, sheep and beef, the ME requirement models of Brookes (2007), Freer *et al*. (2006), SCA (1994), CSIRO (2007) and NZI have a high degree of commonality. The NZI model largely follows Freer *et al*. (2006). Differences between the models and the one implemented for OVERSEER are described.

Estimation of ME requirements for deer was based on Nicol and Brookes (2007) and the NZI as deer are not included in Freer *et al*. (2006), with additional information used as discussed in the text. Estimation of ME requirements for dairy goats is largely based on that for sheep.

OVERSEER uses a mob based approach, and estimates ME intake for a typical animal in the mob for each month. There is an underlying assumption that ME requirements for an animal using mean mob characteristics is the same as the sum of ME requirements for individual animals in a mob. Hence individual animal and mob-based methods can be interchanged. Internally, some calculations are undertaken on a daily basis. The methods shown in sections 4.1 to 4.9 are based on a daily model. Section 5 outlines how the model adapts this to a monthly time step to obtain outputs required by other parts of the model.

1.2. Workings of the technical manual

The aim of the technical manual is to provide a level of detail so that users of OVERSEER can clearly see the underlying principles and sources of data used to build the components of the model. This technical chapter is part of a series of technical manuals currently under development to explain the inner working of the OVERSEER engine.

In the equations in this manual, units are shown using ( ) and cross-references other equations and sections within this manual or to other chapters of the technical manual are shown using [ ]. Equations with multiple '=' options are cascading alternatives in the order they are considered. The condition is shown on the right hand side. The variable and parameter names used are generally shortened names of the property, and this naming convention is similar to the convention used in the OVERSEER engine model.

1.3. Abbreviations and subscripts used

<u>Abbreviations</u>

DM	Dry matter
DMI	Dry matter intake
ME	Metabolisable energy (MJ)
NE	net energy (MJ)
NZI	New Zealand greenhouse gas emissions national inventory (Ministry of the Environment 2011)
RSU	Revised Stock Units

<u>Subscripts:</u>

antype	animal types within OVERSEER (dairy, dairy replacements, sheep, beef, deer, dairy goats, other)
mon	month of the year

2. ME requirements

The ME requirement sub-model estimates metabolisable energy requirements to attain the production entered by the user, and to maintain the animal. The general structure of the metabolic energy model is common to all animal types and classes, although parameters used within the sub-model are dependent on animal types and classes.

Total ME requirements (MJ ME /animal) are estimated from the ME requirements to maintain the animal, to produce the products (milk, wool, velvet, live weight gain) and for pregnancy. Thus:

Equation 1. MErequirements = MEmaintenance + productionME + MEpregnancy

ME requirements are estimated from net energy (NE) requirements, using energy conversion coefficients that are defined in section 3. Net energy requirements (NE) per day are shown in sections 4.1 to 4.9. Section 5 describes how the components in sections 4.1 to 4.9 are incorporated into OVERSEER.

In the following sections, the methods to estimate the energy conversion coefficients are described in section 3, section 4 describes the daily net energy calculations the mob-based model is based on, and section 5 describes the mob-based model.

3. Energy efficiency coefficients

3.1. Energy density

The energy conversion coefficients for lactation and maintenance require an estimate of energy density (qm), which is estimated as:

Equation 2. qm = dietME/GE

dietME is the average diet ME content (MJ/kg DM intake) [Charactistics of animals chapter].

GE is the gross energy of feed (18.4 MJ/kg DM).

GE reflects the carbohydrate, protein, and fat content of feed such that feeds with high protein or fat content would be expected to have high GE. Based on the summary in CSIRO (2007) it is assumed that gross energy of pasture and all types of supplements are the same. Average diet ME content, and hence qm, will vary between months as pasture ME content, and the proportion of the diet that is supplement, varies.

3.2. Energy conversion coefficients

Energy conversion coefficients to convert net energy to metabolisable energy are:

For lactation

Equation 3. $k_l = 0.35 * qm + 0.42$

qm is the energy density [Equation 2].

For pregnancy

Equation 4. $k_p = 0.13$

For maintenance

Equation 5. $k_m = 0.85$ for milk diets.

Equation 6. $k_m = 0.35 * qm + 0.503$ otherwise [CSIR0, 2007]..

qm is the energy density [Equation 2].For wool

Equation 7. $k_{wool} = 0.18$

For live weight change

Equation 8. k_g = k_l / 0.84 — lactating animal losing weight
= k_l * 0.95 — other lactating animals
= k_m / 0.8 — non-lactating animals losing weight
= k_{gf} * (1 - pmilk) + 0.7 * pmilk — otherwise

pmilk is the proportion of milk in the diet.
0.7 is the energy conversion coefficient for milk.

and where

Equation 9. k_{gf} = 0.042 * dietME + 0.006

dietME is the average diet ME (MJ/kg DM intake) [Animal model chapter].

For mature lactating animals, the change in live weight was based on the monthly live weight change, and assumed that the energy conversion coefficients for the average herd live weight gain was the same for non-lactating animals.

Freer *et al*. (2006) and CSIRO (2007) expanded the estimation of kg to:

Equation 10. k_g = k_{gf} * pforage + kgs * psupplements + 0.7 * pmilk

pforage is the proportion of forage pasture in the diet.
psupplements is the proportion of supplements in the diet.
pmilk is the proportion of milk in the diet.

where

Equation 11. k_{gf} = 0.035 * dietME * flegume * ftime — for temperate pastures
= 0.042 * dietME + 0.006 — for tropical pastures

dietME is the average diet ME (MJ/kg DM intake) [Animal model chapter].
flegume = 1 + 0.33 legume
legume is the proportion of legume in diet.
ftime = 1 + 0.12 8 (lat * sin(0.0172 day)/40))
lat is the latitude (negative in the south).
day is the day of year.

and where

Equation 12. k_{gs} = 0.042 * dietME + 0.006

dietME is the average diet ME (MJ/kg DM intake) [Animal model chapter].
0.7 is the energy conversion coefficient for milk.

However, this has not been implemented, as it is unclear whether the seasonal variation in kgf is a reflection of seasonal variation of pasture ME (which includes contribution from legume).

4. Net energy components

4.1. Basal

Basal net energy requirements (MJ/day) were based on the equation in Nicol and Brookes (2007, equation 1) and is estimated as:

Equation 13. $NEbasal = base * K * S * M * Agefactor * lwt^{0.75}$

base is the constant 0.28 MJ/kg $lwt^{0.75}$.

K_{antype} is 1.4, 1.4, 1.0, 1.4, 1.7, 1.25 for dairy, dairy replacements, sheep, beef, deer, and dairy goats respectively.

S is a factor for sex [Equation 14].

M is a factor of milk in the diet [Equation 15].

Agefactor is a factor for age [Equation 17].

lwt is the live weight excluding conceptus and, for sheep, fleece (kg).

The value of K is important as it determines the amount of maintenance requirements, and hence nutrient intake over late autumn /winter and thus N leaching. CSIRO (2007) reported values of K of 1 for sheep and goats, 1.4 for *Bos taurus* and 1.2 for *Bos indicsus*, with intermediate values for crosses between these cattle types. In contrast, Nicol and Brookes (2007) use values of 1 for sheep, 1.3 for beef cattle, 1.5 for dairy cattle and 1.4 for deer. OVERSEER used values of CSIRO (2007) for sheep, dairy cattle and beef cattle. These values are the same as used in the NZI.

Reported values of maintenance ME requirements for deer, expressed as MJ ME/kg $lwt^{0.75}$ (C), are shown in Table 1. Vetharaniam *et al*. (2009) estimated data from the literature and tested the model against growth data, where it performed well. As comparisons, Simpson *et al*. (1978a) indicated C for sheep was 0.32-0.35 MJ ME/kg $lwt^{0.75}$ and Simpson (1978b), who reported values for C of 0.40 and 0.55 for sheep and cattle respectively.

Assuming appropriate values for the terms S and M, and that pasture feed was high quality (feed eaten had an ME content of 11 MJ ME/kg DM), then K can be estimated from C. The estimated K for indoor studies ranges from 1.3 to 1.5. The mean K for indoor studies is about 1.4, similar to cattle, and is consistent with comparisons of Simpson (1978a, b). The estimated K for stags growing outdoors (Fennessey *et al*., 1981) was 2. It is unclear whether this is a consistent effect, and whether it applies to hinds as well as stags.

Therefore, OVERSEER uses the value reported by Nicols and Brookes (2007) of 1.4 for deer. The NZI used the mean of the data from Fennessey *et al*. (1981) to give a value of 1.7. Thus, OVERSEER would estimate intake 18% lower for deer than the NZI.

Table 1. Reported values of C (MJ ME/kg lwt$^{0.75}$) for deer.

Source	Notes	C
Simpson *et al*. 1978a	Male penned calves, start weight 30 kg: winter	0.45
	Male penned calves, start weight 30 kg: summer	0.50
Simpson *et al*. 1978b	Male calves, penned	0.52
Fennessey *et al*. 1981	red deer stags fed indoors in 2 groups: 6-8 months (50-110 kg) and 13-18 months 80-105 kg)	0.57
	113 to 140 kg red deer stags fed outdoors in small paddocks in winter	0.85
Suttie *et al*. 1987	For 45 to 80 kg (5 to 17 month old) red deer fed indoors in pens	
	Hinds	0.52
	Stags	0.57
Semiadi *et al*. 1998	60 to 72 kg (10-14 month old) hind and stag fed indoors in calorimeter chambers	
	Red deer	0.567
	Sambar deer	0.474
Vetharaniam *et al*. 2009	Model validated against measured data: hinds	0.549
	Model validated against measured data: stags	0.582

The value of K for goats was based on the ratio between 'a1' term for sheep and goats as reported by Tedeschi *et al*. (2010), which gave 1.05 for non-dairy goats and 1.25 for dairy goats. CSIRO (2007) used a value of 1 as for goats, based on information presented in SCA (1994).

Seasonal variation in K for cattle and sheep has been reported (see review in National Academy of Science, 2000). Fennessey *et al*. (1981) also indicated that outdoor stag maintenance requirements varied with season, being 30%, 50%, 20% and 10% higher in autumn, winter, spring and summer respectively than that of pen fed stags. Given that K = 1.4 for pen fed stags , then K for outdoor stags would be 1.82, 2.10, 1.68, and 1.54 for autumn, winter, spring and summer respectively (or an average of 1.785). Simpson *et al*. (1978b) noted that deer are more prone to cold stress than sheep or cattle, and this may be part of the difference between indoors and outdoors, and seasonal variation. This effect may also be due to low intake thresholds over winter. Seasonal variation has been ignored until more data is available.

The value of S for mixed sex mobs was taken as the mean between male and female. This value mainly applies to young stock, and assumes 50:50 male: female ratio. Analysis indicates that using 1.075 gives a slightly different answer compared to splitting the mob into sexes. Suttie *et al*. (1987) and Vetharaniam *et al*. (2009) indicated that S for stags maybe less than 1.15 (1.09 and 1.06 respectively) but OVERSEER has used the value of 1.15. Thus the factor for S is estimated as:

Equation 14. S = 1.15 entire males
= 1.075 for mixed sex mobs
= 1 females, castrated males

Freer *et al*. (2006) and CSIRO (2007) set M as (1 + 0.23 * propmilk) if the proportion of milk in the diet (propmilk) is known. SCA (1994) used an alternative approach of:

Equation 15. M = 1 if age > mean weaning day
= 1 + (0.26 - Mage * (age/7)) $M \geq 1$
age is the animal age (days)

where

Equation 16. Mage = 0.26/weeks young can suckle up to

If it is assumed sheep can suckle up to 26 weeks, and cattle to 18 weeks, then Mage can be estimated (SCA 1994). This gives estimated values of Mage of 0.015 for dairy and beef enterprises, and 0.010 otherwise. Nicol and Brookes (2007) did not include M.

The exponential term in Agefactor for age was taken from Freer *et al*. (2006) as it is in days. There is a slight difference (average of about 0.14%) between Freer *et al*. (2006) and Nicol and Brookes (2007), and CSIRO (2007) methods. Agefactor had a minimum value of 0.84 (Freer *et al*., 2006). Thus:

Equation 17. Agefactor = exp(-0.00008 * age)
age is the animal age (days)

4.2. Chewing

NE requirements for chewing and ingesting the feed are dependent on the amount of feed eaten. However, the amount of feed ingested is dependent on maintenance ME requirements, of which ME requirements for chewing and ingesting are included. Therefore, the value is estimated using an iterative process, and the method used for OVERSEER is shown in section 5.2.2.

NE requirements for chewing and ingesting are sometimes referred to as NEgraze, but in systems where animals are fed supplements, NEchew is a more appropriate term. NE for chewing (MJ/day) is estimated as:

Equation 18. NEChew = lwt * SpGraze * DMintake * (0.9 - digest/100)
lwt is the live weight excluding conceptus and, for sheep, the fleece (kg).
SpGraze is an animal enterprise based factor [Equation 20].
DMintake is (kg DM intake) [Equation 19].
digest is the digestibility (%), estimated from dietME

DMintake is not calculated until after animal ME requirements are estimated. Therefore an estimate is made as:

Equation 19. DMintake = MEintake / dietME
MEintake is the total ME requirement (MJ).
dietME is the average diet ME (MJ/kg DM intake) [Characteristics of animal chapter].

Nicol and Brookes (2007) had two spGraze values for deer, with a boundary at 100 kg. This could result in sudden changes in ME requirements when weight crosses the 100 kg threshold. Therefore, spGraze was made into a continuous value between 100 and 300 kg. Value for goats was taken from CSIRO (2007). Thus:

Equation 20. SpGraze	= 0.0025	dairy, beef
	= 0.02	sheep, goats
	= 0.02	deer < 100 kg lwt
	= 0.0025	deer > 300 kg lwt
	= -8.75E-5 * lwt + 0.02875	deer, otherwise

It is assumed that the type of feed (pasture, supplements, crops) has no effect on estimating NE chew other than through average diet ME, and the diet digestibility can be estimated from the diet ME.

4.3. Movement

The NE associated with walking during grazing was based on Nicol and Brookes (2007, equation 3). No additional farm-specific information was found. Thus, NE for movement (MJ/day) is estimated as:

Equation 21. $NEmove = 0.0026 * lwt * SlopeMoveFactor_{slope} * TSR/SD / fmove$

0.0026 is the energy cost of horizontal walking (MJ/km/kg)

lwt is the live weight excluding conceptus and, for sheep, fleece (kg).

SlopeMoveFactor is 1, 1.5, 1.7, 2 for average topography of flat, rolling, easy hill and steep hill respectively.

TSR/SD is the relative stocking rate, where SD is the threshold for grazing density (animals/ha) and TSR is the current grazing density (animals/ha).

fmove is a factor for the amount of pasture on offer [Equation 22].

where

Equation 22. $fmove =((0.000057 * PastureMass_{slope, antype} * 1000) + 0.16$

PastureMass is the pasture mass at grazing (T DM/ha) [Characteristics of animals chapter].

The average topography for an animal type is average topography of the blocks that animals grazed. This is currently estimated on an annual basis.

SlopeMoveFactor were taken from Nicol and Brookes (2007, Appendix – Costs of grazing). It was assumed that flat, easy, and hard hill corresponded to the OVERSEER topography classes of flat, rolling, and steep hill country. The value 1.7 was added to represent easy hill class within OVERSEER.

StockPol uses a slightly different procedure as it was considered that the current method overestimated NEmove (Litterland, pers com.). StockPol estimated SlopeMoveFactor as:

Equation 23. $SlopeMoveFactor_{slope} = (1+TAN(slope * 3.14/180))$

Assuming that flat, rolling, and steep hill corresponded to slopes of 0, 20 and 35 degrees, this gave values of $SlopeMoveFactor_{slope}$ of 1, 1.36 and 1.70 respectively, which are lower than the current values. .

Pasture mass at grazing is assumed to be constant over the year.

It was assumed that when animals are on a pad, NE for movement is zero. It is assumed that NE for movement is not affected by factors such as strip grazing, feeding of supplements, or pasture types.

Freer *et al*. (2006) and CSIRO (2007) set the threshold grazing density (TSR) as 40 and 5 head/ha for sheep and cattle respectively. Although OVERSEER can estimate average grazing density, it does not know the actual grazing density. For most dairy platforms, grazing density would be high. It is also likely to be high on other systems where break feeding and rotational grazing are practiced. Therefore, following Nicol and Brookes (2007), TSR/SD was set to 0.07 for dairy animals, and 1 for other animal types.

4.4. General activity

NE required for general activity is the NE associated with other activities such as finding water, shelter. For dairy, an additional term for walking to the farm dairy is included. No additional farm-specific information was found other than that in Nicol and Brookes (2007, equation 3). Thus, NE for activity (MJ/day) is estimated as:

Equation 24. NEactivity = (lwt * ((0.0026 * Hkm) + (0.028 * Vkm)))

lwt is the live weight excluding conceptus and, for sheep fleece (kg)
0.0026 is the energy cost of horizonal walking (MJ/km/kg)
0.028 is the energy cost of vertical walking (MJ/km/kg)
Hkm is the horizonal distance walk (km) [Characteristics of animals chapter].
Vkm is the vertical distance walk (km) [Characteristics of animals chapter].

It was assumed that that the vertical and horizontal distances walked is only dependent on average topography.

It was assumed that dairy cows walk a distance of 0. 5 km to get from the paddock to the milking shed. This is equivalent to a longest race length of about 0.9 km. Thus, to get to the milking shed and return requires four trips per day with twice-a-day milking. The average distance needs validating, and could vary with farm size. Thus the net energy requirement (MJ/day) to move to and from the dairy shed is estimated as:

Equation 25. Movedairycow = 0.0026 * lwt * Walkkm

0.0026 is the energy cost of horizonal walking (MJ/km/kg).
lwt is the live weight excluding conceptus (kg).
Walkkm = 0. 5 * 4
0. 5 is the average distance to shed (km).
4 is the number of times distance cover with twice a day milking.

4.5. Pregnancy

The daily NE requirements for gestation are based on Freer *et al*. (2006), except the term BC_{foet} is replaced by CF (Litherland pers com.). CF is an estimate of the effect of animal condition on pregnancy requirements. Thus, NE for pregnancy (MJ/day) for sheep is estimated as:

Equation 26. NEpregnancy = n * BirthWt * 1.43 * 4.33 * (4.37 * 0.965) / GL * NEpreg2 * CF

n is the number of young.

BirthWt is the average birth weight (kg)

GL is the gestation length (days) [Characteristics of animals chapter].

NEpreg2 = exp(0.965 * (1 - RA) + 4.37 * (1 - exp(0.965 * (1-RA))))

RA is the proportion of the gestation period [Equation 28].

CF is a condition factor [Equation 29].

Dairy goats are assumed to be the same as sheep. For dairy and beef, a similar method to sheep is used. Thus, NE for pregnancy is estimated as:

Equation 27. NEpregnancy = n * BirthWt * 1.80 * 4.11 * (343.5 * 0.0164) / GL * NEpreg2 * CF

n is the number of young

BirthWt is the average birth weight (kg).

GL is the gestation length [Characteristics of animals chapter]

NEpreg2 = exp(0.0164 * (1 - RA) + 343.5 * (1 - exp(0.0164 * (1-RA))))

RA is the proportion of the gestation period [Equation 28].

CF is a condition factor [Equation 29].

The proportion of the gestation period (RA) is estimated as:

Equation 28. RA = DayConception / GL

DayConception is the number of days since gestation started [5.2.5.6].

GL is the gestation length [Characteristics of animals chapter].

The condition factor is estimated as:

Equation 29. CF = 1 + (RC - 1) * (CW / (NBW * SRW))

RC is the animal condition during gestation, estimated as current weight / normal weight.

CW is the weight at a given time during gestation (kg) [Equation 30].

NBW is the proportion of SRW that birth weight is [Equation 31].

SRW is the standard reference weight (kg) [Characteristics of animals chapter].

where

Equation 30. CW = $BirthWt_n$ * exp(2.20 * (1 - exp(1.77 * (1-RA))))

BirthWt is the average birth weight (kg).

RA is the proportion of the gestation period [Equation 28].

and where NBW is the proportion of SRW that birth weight is, estimated as:

Equation 31. NBW = 0.1, 0.085, 0.07 or 0.055 for 1, 2, 3 or 4 young respectively sheep
= 0.07, 0.055 for 1 or 2 young respectively dairy goats

For deer, equations by Nicol and Brookes (2007) gave too large an estimate when compared to the value in their Table 22. Therefore, an equation was fitted that gives about 440 MJ for a birth weight of 8 kg as published in Table 22. Hence, CF is in units of NE. It is assumed that deer can only have 1 young. Thus, NE for pregnancy for deer is estimated as:

Equation 32. NEpregnancy = (BirthWt / 8) * (-0.2 + 0.2 * exp(0.0173 * DayConception))
BirthWt is the average birth weight (kg) [Characteristics of animals chapter].
DayConception is the number of days since gestation started [5.2.5.6].

and is adjusted for the birth rate (Characteristics of animals chapter).

4.6. Lactation

The NE for lactation varies with species. For dairy and dairy goats, annual milk solids are a required input, and annual milk volume are an optional input. Annual milk volume can be estimated from milk solids. Thus for lactating dairy or dairy goat animals, NE for lactation (MJ/month) is estimated as:

Equation 33. NElactation = Monthmilkyield * NEmilk
Monthmilkyield is the daily milk yield (kg milk/day) [Equation 34].
NEmilk is the NE conent of milk (MJ/kg whole milk) [Characteristics of animals chapter].

For dairy cows and dairy goats, daily milk yield (kg milk/day) is estimated as:

Equation 34. Monthmilkyield = Milkvolume * Milkdensity * propLactMon
Milkvolume is the annual milk volume (l milk/year).
Milkdensity is the density (l/kg) [Characteristics of animals chapter].
propLactMon is the is the proportion of lactation that occurs in a given month [Characteristics of animals chapter].

For lactating sheep and beef animals, a daily milk yield is estimated (Litherland, pers. comm.). For sheep, the effect of multiple young (MLE), different breeds and available pasture are factored into the estimation of daily milk yield. Thus daily milk yield (kg milk/day) for sheep is estimated as:

Equation 35. Daymilkyield = (1.01 *
EXP(0.41 * LN(DayLactation) - 0.0287 * DayLactation)
* MLE * BFM * 1000
+ (0.4144 * ($PastureMass_{slope, sheeep}$ * 1000 -1300))
+ (-1 * $10E^{-4}$ ($PastureMass_{slope, sheeep}$ * 1000 - 1300)^2))))
/ 1000
DayLactation is the days since start of lactation [section 5.2.5.7].
MLE is a factor for multiple young [Equation 36].

BFM is a factor for breed [Equation 38].

PastureMass is the pasture mass at grazing (kg DM/ha) [Characteristics of animals chapter].

The factor for multiple young (MLE) is estimated as:

Equation 36. $MLE = 1.002884363 * prop_1 + 1.287356551 * prop_2 + 1.368048232 * prop_3 + 1.368048232 * prop_4$

prop is the proportion of young that are singles, twins, that are weaned [Characteristics of animals chapter].

Around 70% of lamb mortality that occurs between birth and weaning occurs within 48 hours of birth (Lifetimewool, 2016). Hence it is assumed that lactation is adjusted for the number of animals alive, and this is based on the proportion of young that are singles, twins, etc. at weaning.

There was no information for the effect of quads on MLE. A plot of the constants indicated that the constants were reaching a plateau after triplets and hence the same constant was used for quads as for triplets.

Breed effect for a single animal was originally written as:

Equation 37. $BFM = 1 + (Breedeffect * (3 * (N-1)/(N+1))$

However, this can be translated in the equation shown above for a mob-based model.

Equation 38. $BFM = prop_1 + (1 + Breedeffect) * prop_2 + (1 + (Breedeffect * 1.5)) * prop_3 + (1 + (Breedeffect * 1.8)) * prop_4$

prop is the proportion of young that are singles, twins, etc that are raised [Characteristics of animals chapter].

Breedeffect	= 0.2	EastFriesian
	= 0.1	RomneyEFcross
	= 0.01	otherwise

Daily milk yield (kg milk/day) for beef is estimated as:

Equation 39. $Daymilkyield = 4.26 * DayLactation^{0.113} * (EXP((-4.95\ 10^{-3}) * DayLactation)) + (6.51\ 10^{-4} * (PastureMass_{slope, beef} * 1000 + 200)) + (2.9110^{-1} * BC)$

DayLactation is the days since start of lactation [section 5.2.5.7].

PastureMass is the pasture mass at grazing (kg DM/ha) [Characteristics of animals chapter].

BC is a breeding condition (assumed to be 1).

For deer, no information was found for annual milk yield as for sheep and beef. Therefore, the relationship between fawn weaning weight (kg) and total MJ ME for lactation was derived from Table 23 in Nicol and Brookes (2007). ME for lactation in their Table 26 includes fawn growth. Initial runs using a 55 kg weaning weight fawn indicated that fawn growth while the mother was lactating accounted for 1214 of the 3829 ME. Hence, total lactation ME was reduced by 68% to give ME for lactation. The result was then multiplied by kl to give MJ NE. Milk production is assumed to decrease at a constant rate over the lactation length of 120 days. Thus for lactating deer, NE for lactation (MJ NE) is estimated as:

Equation 40. NElactation = TotalLactationNE * dayfactor * 0.68

TotalLactationNE is the net energy for fawn growth [Equation 41].

dayfactor is the proportion of lactation that occurs on a given day [Equation 42].

0.68 is the proportion of TotalLactationNE that is due to lactation.

where the net energy for fawn growth (lactation and fawn live weight gain while on the mother) is estimated as:

Equation 41. TotalLactationNE = (52.5 * weaningwt + 812.5) * k_l

weaningwt is the fawn weaning weight (kg) [Characteristics of animals chapter].

k_l is the energy econversion efficiency for lactation [section 3.2].

and the proportion of lactation that occurs on a given day is estimated as:

Equation 42. dayfactor = -0.00013698 * DayLactation + 0.0166202

DayLactation is the days since start of lactation [section 5.2.5.7].

4.7. Live weight change

The equation from Nicol and Brookes (2007) or CSIRO (2007) was used for estimating NE for change in live weight as this equation was more stable when miscoded animal classes were entered, e.g. R3 with R1 weight ranges. These equations incorporate the stage of maturity, and hence the change in fat and protein content as the animals age. Thus, NE for live weight (MJ/day) change is estimated as:

Equation 43. NElwt = lwtchange * 0.92 * EVG

lwtchange is the change in liveweight (kg).

0.92 is the ratio live weight to body weight.

EVG is the energy for liveweight change based on empty body weight (MJ/kg lwt) [Equation 44].

where

Equation 44. EVG = (6.7 + R) + (k1 - R) / (1 + EXP(-6 * (Z - 0.4)))

R is an adjustment for rate of gain or loss [Equation 46].

k1	= 16.5	for large lean breeds of cattle
	= 20.3	otherwise

where

Equation 45. Z = lwt / SRW

lwt is the animal weight (kg) on a given day.

SRW is the standard reference weight (kg) [Characteristics of animals chapter].

and the adjustment for rate of gain or loss is estimated as:

Equation 46. $R = (lwtchange*1000*0.92) / (4*SRW^{0.75}) - 1$

lwtchange is the change in liveweight (kg).

SRW is the standard reference weight (kg) [Characteristics of animals chapter].

The method for assessing adjustment for rate of gain or loss (R) was based on equation for known change in body weight (SCA (1994) and used by Nicol and Brookes (2007)) rather than the method when ME intake is known and gain or loss must be predicted.

Large lean breeds of cattle included Charolais, Chianina, Blonded, Aquitane, Limousin, Maine Anjou and Simmental (CSIRO 2007).

4.8. Wool

NE requirement for wool growth (MJ NE/day) is based on the equation from Freer *et al.* (2006) and is estimated as:

Equation 47. NEwool = 24 * ((YearlyWoolGrowth /365 * 1.15 * 0.7) - 0.004)

24 is the energy content of clean wool (MJ NE/kg wool growing/day).

YearlyWoolGrowth is the annual greasy wool shorn (kg/animal/year).

365 is days in year.

1.15 is the shorn to grown ratio, including animals sold with wool [Sumner pers. comm.].

0.7 is the clean:greasy ratio.

0.004 is the basal wool growth (kg wool growth/day) which is included in basal NE estimation.

OVERSEER assumes uniform wool growth over 12 months. Yearly wool growth is a fixed value, is not dependent on breed, and is not linked to entered annual wool production.

4.9. Velvet

The estimation of energy for velvet growth was based on Fennessey *et al*. (1981) who reported a value of 0.5 MJ ME/day over 100 days for a stag producing 2.4 kg velvet and assuming an efficiency of utilisation of ME of 0.33.

4.10. Stressful conditions (cold, heat, wet, wind)

CSIRO (2007) noted that basal maintenance requirements increase under stressful conditions induced by heat, cold, wet or wind. The effect of cold has been quantified, but not that of heat stress (CSIRO 2007). Woodford and Nicol (2004) noted that:

> *"the effects of cold stress on energy expenditure are episodic and although significant in the short term, there are relatively few of these events over an annual productivity cycle in most New Zealand environments"*

Given this, the impact of stressful conditions has been ignored. However, one of the often-quoted effects of animal shelters/barns is reduced feed and/or better production due to shelter. This is often attributed to reduced cold stress in winter and heat stress in summer, along less energy required for walking.

5. Modelling methods

The ME requirement sub-model is a standalone procedure that is common to all animal types and classes, although parameters used within the sub-model are dependent on animal types and classes.

5.1. Model inputs and outputs

5.1.1. Inputs

The inputs required to run the ME requirement sub-model are shown in Table 2.

Table 2. Input data for calculating metabolisable energy requirements.

Variable	Description
Animal enterprise	dairy, dairy replacements, sheep, beef, deer, dairy goats.
Breed	*animal breed.
Mean birth day	#day of year for mean birthing.
Mean weaning day	#day of year for mean weaning.
Lactlen	*lactation length (days).
StartAgeMonth	#age (months) of mob at the start of the year.
LactatingFemale	**whether lactation occurs in 12 month period (T/F).
GestatingFemale	**whether gestation occurs in 12 month period (T/F).
Male	**mob is male e.g. bulls (T/F).
Mixedsex	**mob is mixed sex e.g. lambs, claves or fawns (T/F)
PercentBorn	#weaning rate (%).
SRW	*standard reference weight (kg)
Currentweight	*average current weight of the animals at the start of the year (kg).
Weaningweight	*weaning weight (kg).
Hkm	*distance walked horizontally in a day (km).
Vkm	*distance walked vertically in a day (km).
WoolGrowth	#yearly wool growth (kg wool/animal/year).
Cmilkfat	*fat content of milk (%).
Cmilkprotein	*protein content of milk (%).
AnnualMilkYield	#annual milk yield for dairy and dairy goats (litres/animal/year).
MonLwtChange	#monthly live weight changes (kg/month/year).
PropOnPads	#proportion of time animals are on pads or under restricted movement.
DietME	#monthly average diet ME content (MJ ME/kg DM).

* described in more detail in Animal characteristics chapter.
** defined by the mob class as defined in the Animal characteristics chapter.
# described in more detail in Animal model chapter.

5.1.2. Outputs

The procedure returns monthly estimates of ME requirements (MJ ME/month):

- total for a typical animal of a mob,
- for each component (movement, general activity, pregnancy, lactation, basal, wool, chewing, live weight change)
- for young animals (< 365 days old) associated with that mob, and
- for animals with pre-wean young, then total ME requirements and ME intake from milk for the pre-weaned young.

The procedure also returns the proportion of intake while lactating.

5.2. Procedure

5.2.1. General procedure

Some components of NE intake are estimated once per month as there is no change in the input data during the month. Thus, OVERSEER estimates an average daily NE requirement for movement, activity, and wool each month.

NE required for basal, pregnancy, lactation and gain are estimated on a daily basis. The requirement for each day is summed and divided by number of days in the month to give an average daily requirement.

The procedure initially calculates variables that are constant throughout the year. Thus MLE, BFM (section 4.6), proportion of births that are single or multiple, NE content of milk, kwool and kp are estimated. In addition, birth weights, weaning age and weaning weight are estimated if these are not supplied.

Next, monthly and daily live weight changes are estimated when these are not supplied (e.g. for mature animals), and then daily calculations of component NE requirements are undertaken. The monthly NE requirements are then estimated.

For animals with pre-weaned animals, ME requirements for the pre-weaned animals are calculated (section 5.2.4). For lactating dairy animals, the proportion of intake while lactating is estimated (section 5.2.5.9).

5.2.2. Estimating NE for chewing

NE requirements for basal, pregnancy, lactation, and live weight change (NEbasal, NEpregnancy, NElactation and MElwt) are estimated daily as described in sections 5.2.6.1, 5.2.6.5, 5.2.6.6, and 5.2.6.7 respectively, and summed to give a total for the month. Average daily ME requirement (MJ ME/day) is estimated by dividing the summed value by number of days in the month to give an average daily requirement. Thus:

Equation 48. $NEbasal_{av} = \sum(NEbasal_{day}) / Numberdays$

Equation 49. $MEpregnancy_{av} = \sum(NEpregnancy_{day}) / k_p / Numberdays$

Equation 50. $MElactation_{av} = \sum(NElactation_{day}) / k_l / Numberdays$

Equation 51. $MElwt_{av} = \sum(MElwt_{day}) / Numberdays$

Numberdays is the number of days in month.

k_p and k_l are energy conversion coefficients [section 3.2].

Average daily NE requirement for movement ($NEmove_{av}$), general activity ($NEactivity_{av}$), and ME requirements for wool ($MEwool_{av}$) and velvet ($MEvelvet_{av}$) is estimated each month using the method described in sections 5.2.6.3, 5.2.6.4, 4.8, and 4.9, with average daily data for each month.

Total ME requirements for a day (MJ ME/day) is estimated using an iterative procedure as $NEchew_{av}$ depends on ME requirements, which includes $NEchew_{av}$. Thus based on initial runs, an initial estimate of $NEChew_{av}$ is set:

Equation 52. $NEChew_{av} = NEbasal * 0.046$

and then $NEChew_{av}$ and ME requirement is then estimated via an iterative process until the change in ME requirements is less than 0.1 MJ. Thus:

Equation 53. $productionME = MElactation_{av} + MEwool_{av} + MEvelvet_{av} + MElwt_{av}$

Equation 54. $MEmaintenance = (NEbasal_{av} + NEChew_{av} + NEmove_{av} + NEactivity_{av}) / km + 0.1 * productionME$

km is energy conversion coefficient for maintenance [section 3.2].

Equation 55. MErequirements = MEmaintenance + productionME + MEpregnancyav

The approach of Freer *et al*. (2006) was used whereby maintenance costs associated with production were added to maintenance rather than to the production components as proposed by Nicol and Brookes (2007).

$NEchew_{av}$ is re-estimated, using MErequirements to estimate DM intake. The process continues until the difference in maintenance requirements (MEmaintenance) between successive estimations is less than 0.1 MJ ME, or five iterations have occurred.

5.2.3. Monthly ME requirements

Monthly ME requirements (MJ ME/month) are then estimated for the full month as:

Equation 56. $MEintake_{mon} = (MEmaintenance + productionME + MEpregnancy) * Numberdays$

Equation 57. $MEbasal_{mon} = NEbasal_{av} / k_m * Numberdays$

Equation 58. $MEchew_{mon} = NEchew_{av} / k_m * Numberdays$

Equation 59. $MEmove_{mon} = NEmove_{av} / k_m * Numberdays$

Equation 60. $MEactivity_{mon} = NEactivity_{av} / k_m * Numberdays$

Equation 61. $MEpregnancy_{mon} = MEpregnancy_{av} * Numberdays$

Equation 62. $MElactation_{mon} = MElactation_{av} * Numberdays$

Equation 63. $MElwt_{mon} = MElwt_{av} * Numberdays$

Equation 64. $MEwool_{mon} = MEwool_{av} / k_{wool} * Numberdays$

Numberdays is the number of days in month

k_m is energy conversion coefficient for maintenance [section 3.2].

The proportion of ME while lactating is also estimated (5.2.5.9).

5.2.4. Pre-weaned animals

Pre-weaned animals are the young of breeding females between birth and weaning. For dairy systems, weaning in this context is defined as weaning from milk, which is typically about 90 days from birth.

For lactating females with young, the procedure in section 5.2.1 is used except that data for pre-weaning animals is supplied to the daily procedure. The main changes are:

- S (sex factor for basal requirements) is set to 1.075 as unweaned animals are not sex segregated
- For sheep, yearly wool growth is set at 2 kg/year

- Average daily live weight change (kg/day) is estimated as:

Equation 65. AvDailyLwtChange = (Weaningwt - meanbirthwt) / Weaningage

Weaningwt is the weaning weight (kg).

Weaningage is the weaning age (days).

meanBirthWt = $\sum(birthwt_n * prop_n)$

To prevent young animals (e.g. 1 year old heifers) having young, the condition for determining whether pre-wean animals are present is:

Equation 66. (Weaningage > 0) and LactatingFemale

and (StartDayAge > $SpLactatingAge_{antype}$)

and (PreviousDayLaction < Weaningage)

and (PreviousDayLaction + 1 > 0)

$SpLactatingAge_{antype}$ is the minimum age that lactation can occur [Characteristics of animals chapter].

5.2.5. Properties

5.2.5.1. *Weaning age*

Weaning age is estimated as:

Equation 67.

Weaningage	= 90	for dairy weaners fed milk
	= 4	for dairy
	= MeanWeaningday – Meanbirthday	Meanbirthday < MeanWeaningday
	= 365 - Meanbirthday + MeanWeaningday	otherwise

MeanWeaningday and Meanbirthday are inputs [Table 2]

5.2.5.2. *Age in months at start of calculations*

The age of the animals (in months) at the start of the calculation period is estimated as:

Equation 68.

startAgeMonth	= $MixedMonth_{antype}$	if mixed age
	= entered value	[Table 2]
	= $MatureMonth_{antype}$	if StartAgeMonth = 0

$MixedMonth_{antype}$ is the average age (days) of mixed age flock [Characteristics of animals chapter].

$MatureMonth_{antype}$ is the age (months) when animals are mature (weight gain is zero) [Characteristics of animals chapter].

5.2.5.3. *Age in days for each month*

The age of the animals (in days) at the start of the calculation period is estimated as:

Equation 69. DayAge = actualAge * 365/12

actualAge = startAgeMonth + (month - startmonth) if month ≥

startmonth
= startAgeMonth + (12 - startmonth) + month otherwise

startAgeMonth [section 5.2.5.2]

startMonth is the the month the calculation starts from.

month is the month the calculation is for.

5.2.5.4. *Live weights*

Live weight at the beginning of the calculation is estimated as:

Equation 70. lwt = BaseWeight – diffwt dairy (lactating females)
= Baseweight * $femalelwt_{month}$ lactating females
= Baseweight mature animals
= currentweight other animals

BaseWeight is the herd weight (kg) for dairy or mature weight for other animal types [Characteristics of animals chapter].

diffwt is the difference in weight (kg) from herd weight for given day of lactation.]

$femalelwt_{month}$ is live weight variation with year [Characteristics of animals chapter].

currentweight (kg) is an input value.

5.2.5.5. *Average daily live weight*

Average daily live weight is estimated each month as:

Equation 71. DailyLwtChange = AvLwtChange / $monthdays_{month}$

AvLwtChange = diffwt dairy, DayLactation <= 100
= Matureweight * ($femalelwt_{month}$ – $femalelwt_{month -1}$) lactating females
= Matureweight * ($staglwt_{month}$ – $staglwt_{month -1}$) stags
= MonAvLwtChange non-lactating

$femalelwt_{month}$ is live weight variation with year [Characteristics of animals chapter].

$staglwt_{month}$ is live weight variation with year for stags [Characteristics of animals chapter].

MonAvLwtChange is an input value into the ME sub-model.

Mean live weight for a month is estimated each month as:

Equation 72. Meanlwt = lwt + DailyLwtChange * 15

5.2.5.6. *Day of conception*

For gestating females, the number of days since conception started (Dayconception) at the beginning of the month is estimated as:

Equation 73. DayConception = GL - (Meanbirthday - startday) if startday < Meanbirthday

= 0 DayConception > GL

= GL - (Meanbirthday + 365 - startday) Otherwise

GL is the gestation length (days) [Characteristics of animals chapter].

Meanbirthday is an input value [Table 2].

Startday is the day of year for beginging of month.

During the month, the number of days since conception is incremented by 1.

5.2.5.7. *Day of lactation*

The day of lactation is calculated daily by:

- Day of lactation is set to 1 on the mean birthday
- Day of lactation is increased by one each day.
- Day of lactation is reset to zero if day of lactation equals the lactation length for dairy systems, is equal to mean weaning age for other animal types.

5.2.5.8. *Proportion of milk in the diet*

The proportion of the diet for pre-weaned animals that came from milk was estimated using a back calculation of the term M in the basal equation (section 4.1) to give:

Equation 74. avpropmilk = Σ(pmilk) / dmilk

pmilk = (M -1) / 0.26 if age < mean weaning age, pmilk ≥ 0

= 0 otherwise

M is a factor of milk in the diet [Equation 15, section 4.1].

dmilk is the days in month that milking occurred.

Proportion of the diet for pre-wean animals is estimated monthly using daily calculations of pmilk.

5.2.5.9. *Proportion of intake while lactating*

For lactating animals, the proportion of intake while animals are lactating is estimated each month as:

Equation 75. $\text{PropIntakeWhileLactating} = \text{MElactating} / \text{MEintake}_{mon}$

MEintake_{mon} is monthly total ME requirements [section 5.2.3].

where

Equation 76. $\text{MElactating} = \text{MElactation}_{mon} + \text{MEother} * \text{plactating}$

MElactation_{mon} is monthly ME for lactation [section 5.2.3].

$\text{MEother} = \text{MEpregnancy}_{mon} + \text{MEwool}_{mon} + \text{MElwt}_{mon} + \text{MEvelvet}_{mon} + \text{MEmaintenance}_{mon}$

$plactating = dayslactating / DaysInMonth_{month}$

dayslactating is the number of days lactation occurs within the month.

ME for lactation is only calculated for days that lactation is occurring and hence doesn't need to be adjusted by plactating. In theory, ME for live weight change should be partitioned between lactation and non-lactation phase as energy efficiency coefficients differ, but this was deemed unnecessary given the use of the variable.

5.2.5.10. *Once-a-day milking factor*

For lactating dairy animals, there is an input option to select the occurrence of once a day milking. OAD used in the calculation of net activity is estimated as:

Equation 77. $OAD = \Sigma(pOAD)$

pOAD	= 0.5	if always once-a-day milking
	= 0.5	Daylactation < 30 and once-a-day milking is at the beginning of the season
	= 0.5	if Daylactation > lactlen -30 and once-a-day milking is at the end of the season
	= 0.5	if Daylactation > (lactlen/2) and once-a-day milking is after Xmas
	= 1	otherwise (twice a day milking)

Daylactation is the day of lactation [section 5.2.5.7].

lactlen is the lactation length (days) [Characteristics of animals].

5.2.6. Average daily requirements

The net energy components described in section 4 are modified to fit a mob-based model, to reduce calculation load, and to cater for management options not included in the methods. These modifications are listed in the following sections.

5.2.6.1. *NE for basal*

NE for basal ($NEbasal_{day}$) is calculated using the method shown in section 4.1.

5.2.6.2. *NE for chewing*

NE for chewing ($NEchew_{day}$) is calculated monthly using the method shown in section 4.2, except using average monthly live weight, and estimated iteratively using the method in 5.2.2.

5.2.6.3. *NE for movement*

NE associated with walking during grazing ($NEmove_{day}$) is calculated monthly using the method shown in section 4.3 except using average monthly live weight, and assuming that it is zero if animals are on a pad. Thus:

Equation 78. $NEmove_{day} = NEmove * (1 - propPad_{mon})$

NEmove is the net energy associated with walking during grazing (MJ/month) [section 4.3].

propPad is the proportion of animals that are on pads in a given month [Animal porperties].

5.2.6.4. *NE for general activity*

NE for general activity is calculated monthly using the method shown in section 4.4 except using average monthly live weight, and assuming that it is zero if animals are on a pad. Activity associated with dairy cows walking to the shed is adjusted by the proportion of the month that lactation occurs, and whether once a day milking is practiced.

Equation 79. $NEactivity_{mon} = NEactivity * (1 - propPad) + \sum Movedairycow * prop_{mon} * OAD$

NEactivity is the net energy for activity (MJ/month) [section 4.4].

propPad is the proportion of animals that are on pads in a given month.

Movedairycow is energy requirement for cows moving to and from the shed [section 4.4].

$prop_{mon}$ = dayslactating / monthdays

dayslactating is the number of days lactation within month.

monthdays is the number of days in month.

OAD = Σ(pOAD)

pOAD is a factor for once a day milking options [section 5.2.5.10].

Currently, OAD applies to all dairy milking mobs.

5.2.6.5. *NE for pregnancy*

The daily method was changed to take account of the proportion of animals with multiple births by using average birth weight for animals with young (Characteristics of animal chapter). It was assumed that for mated animals that successfully become pregnant but lose their progeny prior to birth, that this loss occurred in the early stages of pregnancy and hence the effect of NE for pregnancy was negligible. Thus NE for pregnancy (MJ/day) is estimated as:

Equation 80. $NEpregnancy = \Sigma_n(NEpreg * prop_n) * birthrate$

$NEpreg_{daily}$ is the net energy for pregnancy (MJ/day) [section 4.5].

n is the number of young (1, 2, 3 or 4).

$prop_n$ is the proportion of mob with 1, 2, 3 or 4 young born [Characteristics of animals chapter].

fconception is a factor to account for the difference between weaning rate (entered data) and birth rate.

Energy requirements for the conceptus increase exponentially towards birth. The model assumes that most of the conceptus losses occur in early pregnancy, and hence accounting for the extra energy requirements of lost conceptus would have negligible effect on intake. For dairy systems, cows that lose their conceptus are assumed to be culled from the herd, and hence reflected in the number of animals.

The term RC in Equation 29 was set to 1, hence CF is one as it is assumed that the animals are in good condition throughout gestation.

5.2.6.6. *NE for lactation*

The method in section 4.6 is used each day that lactation occurred to estimate $NElactation_{day}$. OVERSEER assumes fat and protein, and hence NE content of milk, and pasture mass at grazing, was constant over the year. See Characteristics of animals chapter for additional information.

For sheep, the effect of multiple births is capture in the factor for multiple young (MLE, Equation 36, section 4.6) and the proportion of animals with multiple young (Characteristics of animals chapter). For sheep with weaning rates less than 100%, and for other animal enterprises, milk yield is reduced by multiplying by the weaning rate to account for animals that have lost their young.

The model assumes that the loss of young between birth and weaning predominantly occurs close to birth, and hence lactation is modified using weaning rate.

5.2.6.7. *ME for live weight change*

NE for live weight change is calculated using daily live weight change (section 5.2.5.5). The energy efficiency coefficient for live weight (kg) varies with proportion of milk in the diet or whether animals are lactating. As kg may change within the month, ME for live weight change ($MElwt_{day}$, MJ/day) was also estimated daily. Thus:

Equation 81. $MElwt_{day} = NElwt / k_g$

$NElwt_{daily}$ is the net energy for live weight gain (MJ/day) [section 4.7].

k_g is the energy efficiency for live weight change section 3.2].

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