SHADES OF GREEN USERS MANUAL

GUIDE AND DOCUMENTATION FOR A DAIRY FARM MANAGEMENT SYSTEM CALCULATOR

SHADES OF GREEN
Version 1.1
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THE ORGANIC CENTER - BOULDER COLORADO

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The Organic Center

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PREFACE

The search is on for options to reduce the environmental impacts of agricultural production. Many studies have raised concerns about the greenhouse gas (GHG) and nitrogen pollution associated with livestock operations, including dairy farms. Retailers are looking for credible data on the most efficient and environmentally friendly way to produce milk, cheese, butter, and other dairy products. Policy makers and government agencies are exploring new initiatives and policies that will hopefully support innovation on the farm for the benefit of the environment, the animals on dairy farms, and consumers.

Recent studies on the environmental impacts of dairy farming have reached conflicting and sometimes confusing results. As with most studies of complex, multifaceted systems, the devil is in the details regarding which impacts are included in the scope of a study or model, how such impacts are measured, data sources, and the assumptions embedded in analytical models. In some cases, analysts publishing results in scientific journals have been unwilling to share their models with The Organic Center, making it impossible to replicate or fully understand model results.

Our initial work on modeling the environmental impacts of dairy production focused just on the pounds of pesticides, animal drugs, and synthetic nitrogen fertilizer not used by organic dairy farms, in contrast to typical conventional dairy operations. A Critical Issue Report released in March, 2009 presented our initial projections and was entitled *Shades of Green: Quantifying the Benefits of Organic Dairy Production* (access this report at http://www.organic-center.org/science.environment.php?action=view&report_id=139.

The Center also offered the Excel-based calculator to anyone requesting it via email. Several hundred people from many countries requested the calculator, and many urged the Center to continue expanding its scope and functionality. Our newly released **Shades of Green (SOG) calculator, Version 1.1** is the result of our effort to do so.

The extensive development work required to create **SOG Version 1.1** was funded in large part by a generous grant from the Packard Foundation. Earlier work on the original calculator was funded by Stonyfield Farm, Organic Valley/CROPP, Horizon, and Aurora Organic Dairy, among other supporters of The Organic Center.

The **SOG calculator** is a work in progress. Users are asked to offer suggestions for expanding and improving the calculator. Future versions of the calculator, the **SOG** user's manual and documentation, and reports based on applications of the calculator will be available via the The Organic Center's website.

Charles Benbrook
Chief Scientist
The Organic Center

ACKNOWLEDGEMENTS

Many people have contributed to the evolution of the **Shades of Green calculator** over the past two years. Several past and current members of the Board of The Organic Center have encouraged us to take on this work including Theresa Marquez and George Siemon of Organic Valley, Michelle Goolsby and Blaine McPeak of Whitewave Foods/Horizon, and Mark Retzloff of Aurora Organic Dairy.

Nancy Hirshberg of Stonyfield Farm provided the original suggestion to develop a calculator and her company provided critical seed money that made it possible to develop the initial version of the calculator.

A team of dairy scientists, industry specialists, and researchers was convened to help The Organic Center develop **Version 1.1 of the SOG calculator**. The Center deeply appreciates their willingness to assist in the design and refinement of the calculator. The members of this team include:

Cory Carman, Carman Ranch, Wallowa, Oregon
Ann Clark, Department of Plant Agriculture, Guelph University
Cindy Daley, Professor, College of Agriculture, Chico State University, Chico, California
Wendy Fulwider, Animal Welfare Specialist, Organic Valley, LaFarge, Wisconsin
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Francis Thicke, Fairfield, Iowa
Juan Velez, VP Farm Operations, Aurora Organic Dairy, Boulder, Colorado
Gary Wegner, Circul8 Systems, Spokane, Washington

Working as a consultant to the Center, Cory Carman contributed significantly to the design of the calculator, and especially the work required to project methane emission from dairy management systems. Karie Knoke, KComp Solutions of Sandpoint, Idaho, has drawn fully on her extensive skills building user friendly analytical models within Microsoft Excel. We appreciate her patience in working through so many additions and changes as the team came up with a new or better idea for various aspects of the calculator.

Thanks to Karen Benbrook for desktop publishing this user's manual, and for providing support throughout the long process required to complete and release **SOG Version 1.1.**

Chuck Benbrook

I. OVERVIEW AND INTRODUCTION

The **Shades of Green (SOG)** calculator is designed to estimate milk and meat production, feed intakes, inputs required, wastes generated, environmental impacts, and the economic performance of alternative dairy farm management systems. The basic unit of analysis is a single lactating cow and the animal population required to support a single cow in production over a year. The supporting animals include dry cows, replacement heifers and heifer calves. Results are reported over several time frames: an average day, over a single lactation, during a cow's life, and in an average year of a cow's life.

Throughout this user's manual, screen shots from the calculator will be used to help explain the purpose and basis for each set of input parameters and calculations. The screen shots are truncated and only show the columns that appear under **Scenario 1**, whereas the calculator includes up to four scenarios in a given application.

The **SOG calculator** is a work-in-progress. Future versions will include new modules encompassing additional environmental impacts. As more refined models and equations become available to estimate a given parameter, these too will be incorporated. This October 2010 document covers Version 1.1 and will be updated to coincide with the dissemination of each new version of the calculator. The last section in future versions of this first chapter, OVERVIEW AND INTRODUCTION, will summarize the changes made in a newly released version of the calculator. The details of changes made will also be highlighted throughout the subsequent sections of the user's manual.

SYSTEM REQUIREMENTS

The **SOG Calculator Version 1.1**, was developed using Microsoft Excel 2007. It is available online at www.organic-center.org/SOG_Home in three versions: MS Excel 1997-2003, MS Excel 2007, and MS Excel 2010. Windows XP, Windows 7 or Windows Vista or a higher version operating system is required to run this application. Those wishing to use the calculator on an Apple computer are encouraged to download the MS Excel 1997-2003 version.

All worksheets within the calculator are set to optimal viewing at 85% magnification, with the exception of **Steps 8, 9** and **11** (INPUTS DETAIL), where the optimal viewing is set to 75% magnification. A user can increase (zoom out) the magnification without losing the ability to see the values in a cell. However, if the user decreases (zoom in) the magnification below 85%, some of the numbers may appear as "#####", depending on the resolution of the user's monitor.

A. BASIC STRUCTURE

The **SOG calculator** is a free-standing simulation model built in Microsoft Excel that is composed of three sets of interconnected worksheets:

- The first set of worksheets characterize the scenarios addressed in a given application and begins with APPLICATION SETUP, which specifies up to four scenarios in a given application.
- The next four CHOSEN PARAMETERS worksheets provide a complete accounting of all input

parameter values embedded in the **15 Steps** throughout the calculator.

- The second set of worksheets report the detailed RESULTS TABLES for a given application of the calculator in each of up to four scenarios.

- The third set of worksheets contains the **15 operational steps** of the calculator where input variable values are specified and then used in making a series of calculations.

APPENDIX worksheets in the SOG Calculator provide further explanation of the equations embedded in the calculator, OPTIONS chosen for various parameters, and DEFAULTS used to initialize the Calculator.

Application Setup

The first worksheet in the **SOG calculator**, APPLICATION SETUP, allows the user to establish the name of the application and define up to four scenarios. The application name is then displayed in the upper right hand corner of all the worksheets in **Steps 1-15** and the RESULTS TABLES. The scenario titles are also displayed in the corresponding, color-coded columns for each scenario. **Scenario 1** is blue, **Scenario 2** is green, **Scenario 3** is orange and **Scenario 4** is purple throughout the calculator.

Four scenarios can be modeled in a single application of the calculator (see below). Scenarios can differ across many parameters or just a few, for example, by level of production, reliance on pasture, feed rations, or manure management systems.

“Shades of Green” Dairy Farm Management System Calculator, Version 1.1				
Initial Setup of Application Scenarios				
Name of Application:	*Appl_Name_Date*			Scenario Descriptions
Scenario 1 Title:	Dairy Farm 1	Description of Scenario 1:	☐ Organic	Detailed Description of Dairy Farm 1
Scenario 2 Title:	Dairy Farm 2	Description of Scenario 2:	☐ Organic	Detailed Description of Dairy Farm 2
Scenario 3 Title:	Dairy Farm 3	Description of Scenario 3:	☐ Organic	Detailed Description of Dairy Farm 3
Scenario 4 Title:	Dairy Farm 4	Description of Scenario 4:	☐ Organic	Detailed Description of Dairy Farm 4

In a typical application, it may be helpful to think of **Scenario 1** as a baseline, representing a specific farm or average values across a set of farms sharing many characteristics. **Scenarios 2, 3** and **4** could then differ from **Scenario 1** in one or several ways, reflecting differences between two groups of farms or projecting the consequences of a given change in management systems on a specific farm.

> Important Note – Each scenario that represents an organic farm should have a check mark in the ORGANIC box embedded in the scenario description line in APPLICATION SETUP. This box, when checked, signals the calculator to skip the calculation of synthetic nitrogen fertilizer or synthetic pesticide input applications on feed crops in Step 11 and also affects the summary results in Results Table II.

CHOSEN PARAMETERS

The first four worksheets provide a summary of all user defined values and values where the user has the option of selecting a USER REPORTED, INTERNALLY CALCULATED or established DEFAULT value for parameters within the **15 operational steps.**

The four CHOSEN PARAMETERS worksheets are organized as follows:

- Part I. Parameters Related to Production **(Steps 1-5)**
- Part II. Parameters Related to Inputs **(Steps 6-12)**
- Part III. Parameters Related to Nutrient Excretions **(Step 13)**
- Part IV. Parameters Related to Greenhouse Gas Emissions **(Steps 14-15)**

An example of the first CHOSEN PARAMETERS worksheet is shown below.

Throughout the **15 operational steps** in the **SOG calculator**, a given parameter value can be set in up to three ways: a USER REPORTED value, an INTERNALLY CALCULATED value, or a DEFAULT value. In a few cases, addition options are provided when, for example, there are several recognized formulas to calculate a

Part I - Parameters Related to Production

	Parameter Values			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Step 1 - Herd Profile				
Step 1.1 Dairy Herd (Adult Cows)				
Percent of Lactating Cows in Dairy Herd	86.0%	86.0%	86.0%	86.0%
Step 1.2 Number of Replacements Needed to Sustain Herd				
Involuntary Cull Rate for Lactating Cows	21.2%	21.2%	21.2%	21.2%
Voluntary Cull Rate for Lactating Cows	2.4%	2.4%	2.4%	2.4%
Death Rate for Lactating Cows	5.7%	5.7%	5.7%	5.7%
Cull Rate for Dry Cows	2.0%	2.0%	2.0%	2.0%
Death Rate for Dry Cows	5.7%	5.7%	5.7%	5.7%
Step 1.3. Replacement Stock				
Death Rate for Heifers > 1	1.8%	1.8%	1.8%	1.8%
Death Rate for Weaned Heifers < 1	1.8%	1.8%	1.8%	1.8%
Death Rate for Unweaned Heifers	7.8%	7.8%	7.8%	7.8%
Number of Cows per Bull	40	40	40	40
Breed	Holstein	Holstein	Holstein	Holstein

Part I - Parameters Related to Production

	Update Parameters to			
Variable Name	**Alternative Scenario 1**	**Alternative Scenario 2**	**Alternative Scenario 3**	**Alternative Scenario 4**
Lact_Cows				
Cull_Rate_Involuntary_Lact_Cows				
Cull_Rate_Voluntary_Lact_Cows				
Death_Rate_Lact_Cows				
Cull_Rate_Dry_Cows				
Death_Rate_Dry_Cows				
Death_Rate_Heifers				
Death_Rate_Weaned_Heifers				
Death_Rate_Unweaned_Heifers				
Bull_Can_Impregnate				

given value like methane emissions per unit of manure excretion, as in Step 15.
Users must select the parameter value of choice by clicking the radio button associated with one of the options for specifying a given parameter value. The CHOSEN PARAMETERS worksheets bring together all of the input parameter values chosen by the user, in each scenario for **Steps 1-15.** The CHOSEN PARAMETERS worksheets are structured to facilitate assessment of changes in parameter values across scenarios and applications. If a user changes a parameter value in, for example, **Step 3**, **Scenario 2**, the value for that parameter in the **Scenario 2** column of the CHOSEN PARAMETER worksheet will be automatically updated.

> Important Note – The reverse is not true. Changing an input parameter value in a CHOSEN PARAMETERS worksheet does not change the value in the step where the input parameter is first introduced and used in the calculator.

In each of the four CHOSEN PARAMETERS worksheets, the first four colored columns record the user-chosen or specified input parameter values in each of the four scenarios in the current application. The column VARIABLE NAME is presented to help the user recognize where and how different parameters are embedded in equations throughout the calculator. In any cell where a value is calculated, the formula used and input variables within the equation will be visible in the "fx" function box in Excel, directly above the first row in any worksheet.

The four columns on the right of each CHOSEN PARAMETERS worksheet – under the heading UPDATE PARAMETERS TO – give the user a clean workspace to specifiy changes to input parameters to be made in a new or modified application, in any one or all four of the scenarios.

Once a set of changes in input parameter values are decided upon and recorded in the far-right set of columns, a user should print the worksheet and use it as a reference as the changes are made in each of the relevant **Steps** in the body of the calculator.

RESULTS TABLES

Four RESULTS TABLES appear directly after the CHOSEN PARAMETERS worksheets. The values in these results tables are all drawn from the **15 operational steps.** When an input parameter value is adjusted in any given step, the change will lead to differences in one or more calculations of production, inputs, or waste generation. These differences will also automattically update values and calculations that will appear in the results tables.

The four RESULTS TABLES cover:

- Part I. Overview of Milk and Meat Production
- Part II. Overview of Land and Inputs Required in Feed Production
- Part III. Overview of Manure and Nutrient Excretions
- Part IV. Overview of Greenhouse Gas Emissions

Part I. Overview of Milk and Meat Production

Results Table I. briefly recaps the key parameters from Steps 1-5 involving the lactating cow, milk and meat production, and gross revenue associated with production. Key parameters include the replacements needed to sustain a herd, the number of years in a cow's life, the number of lactations she has and the average length of her lactations. Milk, calf and meat production is summarized by lifetime and per year of a cow's life. Gross Revenue summarizes the revenue associated with milk, meat and calf sales during a cow's productive lifetime and per year of life.

Results Table Part I. Overview of Milk and Meat Production During a Lactating Cow's Productive Life				
	Scenario 1 Dairy Farm 1			
Replacements Needed to Sustain Herd				
Heifers	30.4%	as a percent of adult cows in herd		
Heifers to be Born	41.6%	as a percent of adult cows in herd		
Cow's Productive Life				
Years of Life	4.28	years		
Number of Lactations	2.0	lactations		
Length of Lactations	356.5	days		
Milk Production			**Converted Values**	
Per Day (Unadjusted)	60.0	lbs	27.2	kgs
Per Day (ECM)	61.5	lbs	27.9	kgs
Per Lactation (ECM)	21,937	lbs	9,950	kgs
Lifetime (ECM)	43,874	lbs	19,901	kgs
Per Year of Life (ECM)	10,239	lbs	4,644	kgs
Calf Production				
Lifetime	1.76	calves		
Per Year of Life	0.41	calves		

Milk production is reported in two ways: Unadjusted values and "Energy Corrected Milk" (ECM). ECM takes into accout the nutritional quality differences between milk associated with levels of fat and protein. ECM is the measure of milk production most commonlyused in dairy science research.

Results Table Part I. Overview of Milk and Meat Production During a Lactating Cow's Productive Life (continued)

Meat Production				
Meat from Cow at Slaughter	676	lbs	306	kgs
Meat from Calves				
Lifetime	895	lbs	406	kgs
Per Year of Life	209	lbs	95	kgs
Total Meat Production				
Lifetime	1,571	lbs	712	kgs
Per Year of Life	367	lbs	166	kgs
Gross Revenue				
Days in Diverted Milk Per Lactation	5.0	days		
Revenue from Unadjusted Milk Production Less Diverted Milk				
Lifetime	$ 5,365.62			
Per Year of Life	$ 1,252.21			
Revenue from Meat				
Lifetime	$ 2,671.84			
Per Year of Life	$ 623.55			
Revenue from Calf Sales				
Lifetime	$ -			
Per Year of Life	$ -			
Total Gross Revenue				
Lifetime	$ 8,037.46			
Per Year of Life	$ 1,875.76			

Part II. Overview of Land and Inputs Required in Feed Production

Results Table II recaps Steps 6-11 by summarizing the acres required to produce feedstuff over the course of a lactating cow's productive life as well as crop inputs(synthetic nitrogen, herbicides and insecticides) used to produce associated feedstuff. They are measured for one lactating cow and her supporting herd by kg of daily milk, per day, per lactation, within a lifetime and per year of life.

Results Table Part II. Overview of Land and Inputs Required in Feed Production During a Lactating Cow's Productive Life

	Scenario 1 Dairy Farm 1			
Acres Required for Feed Production				
Acres per Feed Type	**Total**	**Prime Row**	**Other**	
Forages	0.0093	0.0037	0.0056	acres/day
Grains	0.0010	0.0010	0.0	acres/day
Protein Supplements	0.0028	0.0028	0.0	acres/day
Total Acres				
Per Day	0.0131	0.0075	0.0056	acres/day
Per Lactation	4.67	2.66	2.00	acres/lactation
Per Year	4.78	2.73	2.05	acres/year

Crop Inputs for One Lactating Cow plus Supporting Animals				
Synthetic Nitrogen Fertilizer			**Converted Values**	
Per Kg of Milk			0.009	kg/kg of milk
Per Day	0.55	lb/day	0.25	kg/day
Per Lactation	197	lb/lactation	89	kg/lactation
Lifetime	238.51	lb/life	108.19	kg/life
Per Year of Life	55.66	lb/year	25.25	kg/year
Herbicides Used				
Per Kg of Milk			0.00015	kg/kg of milk
Per Day	0.009	lb/day	0.0041	kg/day
Per Lactation	3.21	lb/lactation	1.46	kg/lactation
Lifetime	3.39	lb/life	1.54	kg/life
Per Year of Life	0.79	lb/year	0.36	kg/year
Insecticides Used				
Per Kg of Milk			0.000025	kg/kg of milk
Per Day	0.0015	lb/day	0.0007	kg/day
Per Lactation	0.53	lb/lactation	0.24	kg/lactation
Lifetime	0.65	lb/life	0.29	kg/life
Per Year of Life	0.15	lb/year	0.07	kg/year

"Prime Row" cropland is Class I land under the Natural Resources Conservaton Service's Land Capability Classification system. "Other Land" is all cropland other than Class I land.

Part III. Overview of Manure and Nutrient Excretions

Results Table III. summarizes the manure and nutrient excretions calculated in Step 13 based on the dietary intakes from DMI rations in Step 12. The excretions are broken out for one lactating cow, the other animals in the herd and a total of the two combined. The results measure manure, dry matter, nitrogen, phosphorus and potassium excretions per kg of Unadjusted milk and ECM, per day, and Unadjusted milk per lactation, over a lifetime and per year of life.

Results Table Part III. Overview of Manure and Nutrient Excretions During a Lactating Cow's Productive Life

	Scenario 1 Dairy Farm 1			
Nutrient Excretions for One Lactating Cow				
Manure Excretion (ME)			**Converted Values**	
Per Kg of Milk (Unadjusted)			2.32	kg/kg of milk
Per Kg of Milk (ECM)			2.26	kg/kg of milk
Per Day	139.1	lb/day	63.1	kg/day
Per Lactation	49,583	lb/lactation	22,490	kg/lactation
Lifetime	132,862	lb/life	60,265	kg/life
Per Year of Life	31,007	lb/year	14,065	kg/year
Dry Matter Excretion (DME)				
Per Kg of Milk (Unadjusted)			0.30	kg/kg of milk
Per Kg of Milk (ECM)			0.29	kg/kg of milk
Per Day	17.8	lb/day	8.1	kg/day
Per Lactation	6,340	lb/lactation	2,876	kg/lactation
Lifetime	17,416	lb/life	7,900	kg/life
Per Year of Life	4,064	lb/year	1,844	kg/year
Nitrogen Excretion (NE)				
Per Kg of Milk (Unadjusted)			0.015	kg/kg of milk
Per Kg of Milk (ECM)			0.015	kg/kg of milk
Per Day	0.90	lb/day	0.41	kg/day
Per Lactation	322	lb/lactation	146	kg/lactation
Lifetime	831	lb/life	377	kg/life
Per Year of Life	194	lb/year	88	kg/year
Phosphorus Excretion (PE)				
Per Kg of Milk (Unadjusted)			0.0025	kg/kg of milk
Per Kg of Milk (ECM)			0.0025	kg/kg of milk
Per Day	0.15	lb/day	0.07	kg/day
Per Lactation	54	lb/lactation	24	kg/lactation
Lifetime	148	lb/life	67	kg/life
Per Year of Life	35	lb/year	16	kg/year
Potassium Excretion (KE)				
Per Kg of Milk (Unadjusted)			0.0065	kg/kg of milk
Per Kg of Milk (ECM)			0.0063	kg/kg of milk
Per Day	0.39	lb/day	0.18	kg/day
Per Lactation	138	lb/lactation	63	kg/lactation
Lifetime	474	lb/life	215	kg/life
Per Year of Life	111	lb/year	50	kg/year

Results Table Part III. Overview of Manure and Nutrient Excretions During a Lactating Cow's Productive Life (continued)

Nutrient Excretions for Other Animals

Manure Excretion (ME)				
Dry Cow Per Day	81.0	lb/day	36.8	kg/day
Heifer Per Day	52.8	lb/day	23.9	kg/day
Calf Per Day	25.7	lb/day	11.6	kg/day
Dry Matter Excretion (DME)				
Dry Cow Per Day	9.9	lb/day	4.50	kg/day
Heifer Per Day	8.3	lb/day	3.77	kg/day
Calf Per Day	2.9	lb/day	1.33	kg/day
Nitrogen Excretion (NE)				
Dry Cow Per Day	0.6	lb/day	0.26	kg/day
Heifer Per Day	0.3	lb/day	0.12	kg/day
Calf Per Day	0.1	lb/day	0.06	kg/day
Phosphorus Excretion (PE)				
Dry Cow Per Day	0.1	lb/day	0.05	kg/day
Heifer Per Day	0.1	lb/day	0.03	kg/day
Calf Per Day	0.0	lb/day	0.01	kg/day
Potassium Excretion (KE)				
Dry Cow Per Day	0.3	lb/day	0.12	kg/day
Heifer Per Day	0.3	lb/day	0.13	kg/day
Calf Per Day	0.2	lb/day	0.09	kg/day

Results Table Part III. Overview of Manure and Nutrient Excretions During a Lactating Cow's Productive Life (continued)

Total Nutrient Excretions for One Lactating Cow plus Supporting Animals

Percent of Animal to One Lactating Cow (Step 1)	Lactating Cow		100%	
	Dry Cow		16%	
	Heifer > 1		44%	
	Heifer < 1		45%	
Total Manure Excretions (ME)	186.73	lb/day	84.70	kg/day
Total Dry Matter Excretion (DME)	24.33	lb/day	11.04	kg/day
Total Nitrogen Excretion (NE)	1.18	lb/day	0.54	kg/day
Total Phosphorus Excretion (PE)	0.21	lb/day	0.09	kg/day
Total Potassium Excretion (KE)	0.65	lb/day	0.29	kg/day
Total Nutrient Excretions	**213.10**	**lb/day**	**96.66**	**kg/day**

Part IV. Overview of Greenhouse Gas Emissions

Results Table IV. summarizes the methane gas emitted from one lactating cow, the other animals in the supporting herd and the total of the two combined, as calculated from Steps 14-15. Methane gas is produced by enteric fermentation and manure, each of which is reported individually, and then combined in TOTAL METHANE. Results are reported kg of Unadjusted milk and ECM per day, and Unadjuste milk per lactation, within a lifetime and per year of life. The total daily methane gas emitted from all animals is reported at the bottom of the table.

Results Table Part IV. Overview of Greenhouse Gas Emissions During a Lactating Cow's Productive Life

	Scenario 1 Dairy Farm 1			
Methane Emissions for One Lactating Cow				
Methane (Enteric Only)			**Converted Values**	
Per Kg of Milk (Unadjusted)			0.0155	kg/kg of Milk
Per Kg of Milk (ECM)			0.0151	kg/kg of Milk
Per Day	0.93	lb/day	0.42	kg/day
Per Lactation	331	lb/lactation	150	kg/lactation
Lifetime	1,028	lb/life	466	kg/life
Per Year of Life	240	lb/year	109	kg/year
Methane (Manure Only)				
Per Kg of Milk (Unadjusted)			0.0195	kg/kg of Milk
Per Kg of Milk (ECM)			0.0190	kg/kg of Milk
Per Day	1.17	lb/day	0.53	kg/day
Per Lactation	416	lb/lactation	189	kg/lactation
Lifetime	1,292	lb/life	586	kg/life
Per Year of Life	302	lb/year	137	kg/year
Total Methane (CH4)				
Per Kg of Milk (Unadjusted)			0.0349	kg/kg of Milk
Per Kg of Milk (ECM)			0.0341	kg/kg of Milk
Per Day	2.10	lb/day	0.95	kg/day
Per Lactation	747	lb/lactation	339	kg/lactation
Lifetime	2,320	lb/life	1,052	kg/life
Per Year of Life	541	lb/year	246	kg/year

Methane Emissions for Other Animals				
Methane (Enteric Only)				
Dry Cow Per Day	0.93	lb/day	0.42	kg/day
Heifer Per Day	0.62	lb/day	0.28	kg/day
Calf Per Day	0.22	lb/day	0.10	kg/day
Methane (Manure Only)				
Dry Cow Per Day	1.17	lb/day	0.53	kg/day
Heifer Per Day	0.78	lb/day	0.36	kg/day
Calf Per Day	0.27	lb/day	0.12	kg/day
Total Methane (CH4)				
Dry Cow Per Day	2.10	lb/day	0.95	kg/day
Heifer Per Day	1.41	lb/day	0.64	kg/day
Calf Per Day	0.49	lb/day	0.22	kg/day

Total Methane Emissions One Lactating Cow plus Supporting Animals				
Percent of Animal to One Lactating Cow (Step 1)	Lactating Cow	100%		
	Dry Cow	16%		
	Heifer > 1	44%		
	Heifer < 1	45%		
Methane (Enteric Fermentation)	1.45	lb/day	0.66	kg/day
Methane (Manure)	1.82	lb/day	0.83	kg/day
Total Methane Emissions	**3.27**	**lb/day**	**1.48**	**kg/day**

Results are reported in several ways, and usually in both English and metric units. In general, results are reported per day, per lactation, over the cow's lifetime, and the annual average during a cow's lifetime (lifetime total divided by the number of years of life). For two important reasons, the later measure - ***production, inputs used, or wastes generated per year of life*** - is the most important and least biased overall metric of dairy farm performance and impacts. First, this metric takes into account the significant quantity of feed inputs and wastes generated in the first two years of an animal's life, before a first calf is born or first gallon of milk is produced. Second, this metric also reflects the longevity of the animal, and indirectly, the impacts of dairy farm management systems on animal health.

As a general rule of thumb, the longer a cow's productive life, the lower the feed inputs and wastes generated per unit of milk and meat produced. This is, in part, because the feed inputs and wastes over the first two years of life are, in effect, amortized over longer periods of time on farms where cows live longer and are successfully rebred several times.

Accounting for the impact of cow health and longevity on the environmental footprint of dairy production is just as essential as accurately accounting for feed inputs and production levels. As dairy cow genetics and management systems have increased daily milk production, animal health, reproductive performance, and longevity has declined (Chagas et al., 2007; Hadley et al., 2006; Kellogg et al., 2001; Knaus, 2008; McConnel et al., 2008; Moore and Kirk, undated; Olynk and Wolf, 2008; Smith et al., 2000; Thomsen et al., 2006; Tsuruta et al., 2005).

For these reasons, comparing the impacts of dairy farm management systems per average year over a cow's full lifetime is the best option to minimize bias in assessing alternative systems. Acknowledging and addressing this key source of potential bias is especially important in any studies comparing the performance of high-production dairies to low-to moderate-production operations that place a higher premium on cow health and incorporate a larger share of forage-based feeds in rations.

THE FIFTEEN STEPS

Each of the **15 operational steps** within the SOG calculator is discussed at length in subsequent sections of this manual. In brief, they are:

Step 1. Herd Profile – establishes the animals needed to sustain one lactating cow on an ongoing basis, and the body weights of each animal type.

Step 2. Cull and Death Rates – accounts for specific factors determining cull rates and death and downer cow rates.

Step 3. Lactation Profile – establishes the milk production level, milk quality, calculates ENERGY CORRECTED MILK (ECM), and the average length of lactation and dryoff periods.

Step 4. Breeding and Health – records the method of breeding, reproductive performance and outcomes, impacts of embryo loss and abortion on calving intervals, calf production, days of diverted milk from multiple causes, average number of lactations in a cow's productive life, and the average age of cows at the end of their productive life.

Step 5. Total Production – total milk and meat production, and revenue from all production outputs.

Step 6. DMI Required – total dry matter intake required for a lactating cow and sustaining animals in the herd, based on the level of milk production specified, cow size and condition, and the feedstuffs that make up cow rations.

Step 7. Feedstuff Required – feedstuff yield assumptions and DMI conversions for daily animal feed crops.

Step 8. DMI Worksheet – optional detailed worksheet for calculating average annual shares of DMI for specific feeds based on monthly feed rations for the lactating cow.

Step 9. Daily DMI Rations – average daily feed composition as a percent of DMI required per day, for all dairy herd animals.

Step 10. Acres Required – crop acres required to produce the feedstuffs for dairy animals.

Step 11. Inputs – provides estimates of synthetic nitrogen fertilizer and pesticides required to produce feed for dairy animals per lactation, while **Step 11-Detail** breaks this data out per type of dairy animal on a per day basis.

Step 12. Dietary Intakes – measures dietary intakes of crude protein, phosphorus, and potassium by type of dairy animal.

Step 13. Manure and Nutrient Excretions – measures daily manure and nutrient excretions by type of dairy animal.

Step 14. Greenhouse Gas Factors – establishes factors governing greenhouse gases such as climate, waste management systems, and energy requirements.

Step 15. Methane Emissions – calculates average daily enteric and manure-related methane emissions from dairy cattle.

B. USER FLEXIBILITY

The **SOG calculator** is designed to allow users to customize a given application to assess a wide range of alternative systems, inputs, feed rations, and outcomes. The more precise the input data incorporated in an application, the more accurate the estimates of the impacts and performance of the system. In addition, users have the option in several places to select or alter the equation or method used to calculate a particular output value.

Throughout **Steps 1-15,** users are provided several options to specify production system characteristics or input parameter values. In some cases, these options are listed in a drop-down box. For example, in **Step 3. Lactation Profile**, a drop-down box offers three options in specifying the parameter MILKING FREQUENCY. The options are: 2-X (daily), 3-X (daily), and seasonal.

For most input parameters, users can enter a USER REPORTED value, choose a DEFAULT value, or in many cases, rely on the INTERNALLY CALCULATED value:

1. USER REPORTED (UR) – Values known by the user to be correct, or the best estimates in the context of a specific application. UR values might come from farm records, USDA surveys, or published research. UR cells are displayed as white, to help identify where data can be entered by the user.

2. DEFAULT (D) – Default values are currently incorporated throughout the calculator to make it easier for users to carry out a new application. They have been established based on published research, industry and government surveys, IPCC and/or EPA standards, or expert judgment and are intended to reflect average conditions on U.S. dairy farms over the last decade. All DEFAULT values and sources are listed in the last worksheet in the calculator entitled DEFAULT VALUES INCORPORATED INTO STEPS 1 THROUGH 15. Users cannot alter these default values, although they can be changed in a customized application of the calculator. Contact Dr. Charles Benbrook to discuss this option (cbenbrook@organic-center.org).

3. INTERNALLY CALCULATED (IC) – IC values are automatically calculated from other input parameters and/or calculated using widely accepted formulas embedded in the calculator, (All embedded equations and their sources are listed in APPENDIX A of the **SOG calculator**).

The USER REPORTED option provides an opportunity to incorporate in a given application specific details about a dairy farm, or set of related farms by overriding calculated and/or default values for a given parameter. For example, **Step 4.3** establishes the key performance parameter CALVING INTERVAL, which is the average number of days between the birth of one calf and the birth of the next in a given herd of lactating cows. This variable can be USER REPORTED and will also be INTERNALLY CALCULATED by adding together the length of lactation and days in the DRYOFF PERIOD. Both of these parameter values are established in **Step 3.**

> Important Note – When the USER REPORTED and INTERNALLY CALCULATED values for a given variable are the same or similar, the user can be confident that there is internal consistency in the values of related parameters (LENGTH OF LACTATION and DRYOFF PERIOD in the above example of how CALVING INTERVAL is internally calculated).
>
> Sometimes a USER REPORTED value will differ markedly from an INTERNALLY CALCULATED value. Such differences alert the user to inconsistency or error in one or more input parameter values. In general, differences falling in the range of plus or minus 5% to 10% should be expected given that record keeping is never perfect or complete, but larger differences should be investigated and resolved, since the underlying cause may be associated with misunderstanding of the definition of a given calculator parameter or the impacts of a given practice, system, technology, or input.
>
> To flag and address possible cases of inconsistency, a warning message will appear when a USER REPORTED value is chosen over an INTERNALLY CALCULATED value.

This message will appear to the far right of Scenario 4 and states "If UR and IC values differ significantly, check accuracy of input parameter values used in the IC formula."

The basis for, or source of each UR, D, and IC variable in the calculator is, or can be identified using the cells in the SOURCE NO. column to the right of these values; each cell is linked to a footnote below the table in a given worksheet. Additional sources for USER REPORTED values can be described in the footnotes at teh bottom of each worksheet.

SUGGESTED APPROACHES IN USING THE CALCULATOR

In working with the **SOG calculator,** users can begin in two ways:

- Open a "clean" copy of the calculator with no information specifying any of the four scenarios, nor any input values, and fill out all information required to define and run one to four scenarios; or
- Select an existing application of the calculator and modify any combination of input parameters in one to all four of the scenarios to more accurately reflect the conditions on a specific farm or group of farms.

The best way to proceed with the first option – starting with a "clean" copy of the calculator is to download, open, and save **SOG Version 1.1** without any changes; then reopen or resave **Version 1.1,** renaming and saving it as "Appl_Number or Appl_Name_Date," standing for application number X or the name of the application, followed by the date (or any other file name a user prefers). Then, in the renamed file, the user can proceed to make changes in various parameters in one or more of the scenarios, or create one to four totally new scenarios.

Throughout **Steps 1 through 15,** the "clean" copy of the calculator will have the radio button for the DEFAULT (D) values pre-selected for each parameter. In cases where there is an INTERNALLY CALCULATED (IC) value available, then it will be pre-selected. In some instances there is more than one IC value. For example, in the case of **Step 15,** METHANE (ENTERIC ONLY) can be calculated based on different equations. In this case, the EPA-method is selected as the DEFAULT method. This selection can be changed by clicking alternative radio buttons. In **Steps 7, 8 and 9** where the animal rations, crop yields, and details regarding crop production inputs are recorded, there are no radio bottons to select. The D values are incorporated directly into the spreadsheet and should be replaced whenby user or farm specific data are available.

The D and IC values within **Steps 1 - 15** make it easier for a user to carry out a new application of the calculator. A user must specify only five parameters in order for the calculator to produce results otherwise based on D or IC values for other parameters. These five are:

- Breed of animal in **Step 1.4**
- Number of lactations in productive life, **Step 2.4**
- Unadjusted milk production level per day, **Step 3**
- Milk fat content, **Step 3**
- Milk protein content, **Step 3**

The second option for using the **SOG calculator** is to open an existing application that already contains all required input parameter values for one to four scenarios. The user can then alter any one, and up to four, of the scenarios by changing some (or even all) input parameter values.

An application of **SOG** should be designed to answer a discrete set of questions regarding the impact of differences between two or more dairy farm management systems, or changes in a given dairy farm's management system. Common steps in doing so would include first defining or choosing a baseline scenario, reflecting the average or typical circumstances on a farm or a group of closely related farms. **Scenarios 2, 3 and 4** can model how baseline performance parameters will change as a result of various combinations of changes in management.

Over time, The Organic Center and other users of the calculator will develop and make available a growing set of **SOG** applications, which can be drawn upon and adapted by users in developing applications of interest to them.

Once a baseline scenario is established, the other up-to-three scenarios can be used to analyze the impacts of changes in production levels, milk quality, cow health, the mix of feed supporting dairy animals, manure management systems, and many other elements of dairy farm management. If multiple input parameter values are changed in a single scenario, it can be tricky to determine which change accounts for differences in performance, as reflected in changes in the results tables. To get around this problem, **Scenario 2** can be used to model one change, **Scenario 3** to model a second change, and then the two changes can be combined in **Scenario 4**. By comparing the results from these three alternative scenarios, the user will be able to isolate the impact of the two changes, as well as estimate their combined impacts.

STEP 1. HERD PROFILE

Step 1 establishes the animal inventory on a given farm necessary to sustain one lactating cow on a continuous basis. This step covers five categories of animals: lactating cows, dry cows, replacement heifers greater than one year old, heifers less than one year old to assure an adequate number of freshening heifers, and the number of bulls needed for breeding.

Step 1 is the animal demographics of a herd. The feed, land, and inputs required to support this number of animals, along with the wastes generated by these animals, are estimated in subsequent Steps, in light of production levels and the feedstuffs chosen by a farmer.

Cull, death, and conception rates for lactating cows, coupled with information on the average length of lactation and calving interval, are used to determine the number of dry cows and freshening heifers that must be in the herd to assure a supply of freshening cows sufficient to replace lactating cows that leave the milking herd.

STEP 1.1. DAIRY HERD (ADULT COWS)

Step 1. Herd Profile			
	Scenario 1 **Dairy Farm 1**		
Step 1.1 Dairy Herd (Adult Cows)			
	Percent of Adult Cows in Herd	**Percent of One Lactating Cow**	**Source No.**
One Lactating Cow (OLC) as a Percent of Adult Cows:	Choose one:		
- User Reported	○		
- Internally Calculated (based on Length of Lactation; Step 3)	● 86.0%		Step 3
Percent of Dry Cows:	14.0%		1
Dry Cows as a Percent of One Lactating Cow:		**16.2%**	5

ONE LACTATING COW (OLC) is the basic animal unit driving the calculator's estimates of milk production, feed intake, and waste generation. The calculator also incorporates the "shadow" population of dry cows, heifers and calves needed to sustain one lactating cow on a continuous basis **(Step 1.3)**.

OLC can be expressed as a percent of the total number of ADULT COWS in a herd (i.e., lactating cows plus dry cows), and this parameter is a function of the average LENGTH OF LACTATION (LOL) from

Step 2 and CALVING INTERVAL (CI) from **Step 4.**

OLC AS % OF ADULT COWS is calculated as:

$$\text{OLC as \% of Adult Cows} = \left(\frac{\text{LOL}}{\text{CI}}\right)$$

In **Step 1.1,** OLC as a % of ADULT COWS can be USER REPORTED with the data coming from a survey, study, or record keeping service, or it can be a value representative of a known herd or group of herds. This percentage can also be INTERNALLY CALCULATED using the above equation. In general, the longer the average lactation in a herd, the lower the number of dry cows needed.

PERCENT OF DRY COWS (DC) are adult cows that have had one or more calves that are currently dry, expressed as a percent of all cows. DC is INTERNALLY CALCULATED using the formula:

$$\text{DC as \% of ADULT COWS} = 1 - \text{OLC as \% of ADULT COWS}$$

DRY COWS AS A PERCENT OF ONE LACTATING COW (DCOLC) is an indicator of the degree of dependence on dry cows in sustaining one lactating cow in continuous production and is calculated as:

$$\text{DCOLC} = \text{DC} / \text{OLC}$$

STEP 1.2. NUMBER OF REPLACEMENTS NEEDED TO SUSTAIN HERD

Each year a certain number of adult cows leave a herd and must be replaced to maintain the same number of milking cows. **Step 1.2** estimates this number, based on the assumption that all adult cows leaving the herd are replaced by freshening heifers from within the herd. While predominantly the case on most dairy farms, cows leaving the herd can also be replaced by the purchase of adult cows or freshening heifers. The overall environmental impacts associated with a replacement heifer do not differ greatly as a function of where the heifer is raised, assuming the animal is fed the same basic feedstuffs. The long-distance transport of replacements, however, does increase environmental impact.

In general, as the percentage of lactating cows leaving a herd goes up, the number of bred heifers needed to sustain the population of milking cows also rises. The number of replacements needed on a given farm is a key indicator of cow health and longevity (see **Steps 2 and 4**) and also plays an important role in determining the overall environmental impact of a dairy farm (**Steps 13-15**).

As a general rule of thumb, the greater the need for replacements on a given farm, the larger the environmental footprint per lactating cow and per hundredweight of milk produced. The connection between replacement rate and environmental impact reflects the significant portion of a cow's life-long feed intake and waste generation that occurs during the two years prior to the birth of a first calf.

STEP 1.2.1. NUMBER OF REPLACEMENTS NEEDED PER LACTATING COW TO SUSTAIN HERD

Step 1.2 Number of Replacements Needed to Sustain Herd		
Step 1.2.1 Number of Replacements Needed per Lactating Cow to Sustain Herd		
Involuntary Cull Rate for Lactating Cows:	Choose one:	
- User Reported (from Step 2.1)	○ 0.0%	Step 2.1
- Default	● 21.2%	Step 2.1
Voluntary Cull Rate for Lactating Cows:	Choose one:	
- User Reported (from Step 2.1)	○ 0.0%	Step 2.1
- Default	● 2.4%	Step 2.1
Death and Downer Rate for Lactating Cows:	Choose one:	
- User Reported (from Step 2.2)	○ 0.0%	Step 2.2
- Default	● 5.7%	Step 2.2
Total Replacements Needed for Lactating Cows:	29.3%	4

INVOLUNTARY CULL RATE FOR LACTATING COWS (ICRLC) is the percent of lactating cows that leaves the farm each year, destined for slaughter. Major reasons for involuntary culling are incorporated in **Step 2.1**, which serves as a worksheet source for this variable.

ICRLC values can be USER REPORTED or set at a DEFAULT value. The USER REPORTED value is automatically transferred from **Step 2.1,** and will be generated only when a user provides the data required in **Step 2.1**. The DEFAULT value is also established in **Step 2.1**, and represents an extrapolation of the national dairy sector averages as published in the USDA-APHIS, *Dairy 2007-Part I survey* (see **Step 2.1** for details).

VOLUNTARY CULL RATE FOR LACTATING COWS (VCRLC) is the percent of lactating cows that leave the farm for reasons that are not related to health or production. As with the ICRLC, the most common reasons for voluntary culling are incorporated in **Step 2.1**. The user can choose either the USER REPORTED value or the DEFAULT value as extrapolated from the national industry averages published in the USDA-APHIS, *Dairy 2007-Part I.*

DEATH AND DOWNER RATE FOR LACTATING COWS (DDRLC) is the percent of lactating cows in a herd that dies or falls down and remains unable to stand on the farm annually because of disease, during calf delivery, as a result of an injury, or from other causes. Common factors determining death and downer cow rates are addressed in **Step 2.2.** The DEFAULT value is extrapolated from the USDA-APHIS, *Dairy 2007-Part I*, national average death rate for cows.

The expression to caluculate TOTAL REPLACEMENTS NEEDED FOR LACTATING COWS (TRNLC) is: .

$$TRNLC = ICRLC + VCRLC + DDRLC$$

STEP 1.2.2. NUMBER OF REPLACEMENTS NEEDED PER DRY COW TO SUSTAIN HERD

Step 1.2.2 Number of Replacements Needed per Dry Cow to Sustain Herd		
Cull Rate for Dry Cows: - User Reported - Default	Choose one: ○ ● 2.0%	 2
Death Rate for Dry Cows: - User Reported - Default	Choose one: ○ ● 5.7%	 3
Total Replacements Needed for Dry Cows:	1.07%	4

CULL RATE FOR DRY COWS (CRDC) is the percent of dry cows that leave the herd each year because of a health issue or failure to carry a calf to term, or for voluntary reasons. The CRDC default value is extrapolated from information published in the USDA-APHIS, *Dairy 2007-Part I.*

DEATH RATE FOR DRY COWS (DRDC) is the percent of dry cows in a herd that die annually. This percentage is much smaller compared to lactating cows and is extrapolated from the USDA-APHIS, *Dairy 2007-Part I*, which reports the death rate for all adult cows in the herd. The very small percent of dry cows that become downer cows is included in DRDC.

TOTAL REPLACEMENTS NEEDED FOR DRY COWS (TRNDC) is the sum of the CULL RATE FOR DRY COWS (CRDC) and the DEATH RATE FOR DRY COWS (DRDC), multiplied by the PERCENT OF DRY COWS (DC).

The equation is as follows:

$$TRNDC = (CRDC + DRDC) \times DC$$

STEP 1.2.3. TOTAL REPLACEMENTS NEEDED (LACTATING AND DRY COWS)

Step 1.2.3 Total Replacements Needed (Lactating and Dry cows)		
Number of Replacement Heifers Needed to Sustain Herd:	30.4%	4

NUMBER OF REPLACEMENT HEIFERS NEEDED TO SUSTAIN HERD (NRHNSH) equation is:

$$NRHNSH = TRNLC + TRNDC$$

STEP 1.3. REPLACEMENT STOCK

The total number of heifers needed to generate necessary replacement stock from within a herd is estimated in **Step 1.3**. The total number of freshening heifers needed to sustain the milking herd is calculated in **Step 1.2**, but this number underestimates the total number of heifers required because some heifers die, others fail to breed, and some bred heifers fail to cary a calf full term.

These factors are incorporated in the estimate of heifer numbers in **Step 1.3.1.** This step does not account for whether a given heifer was raised on the farm covered in a given scenario, or purchased and brought onto the farm.

STEP 1.3.1 NUMBER OF HEIFERS > 1 YEAR NEEDED TO PRODUCE REPLACEMENTS

Step 1.3. Replacement Stock		
Step 1.3.1 Number of Heifers > 1 Year Needed to Produce Replacements		
Death Rate for Heifers > 1 Year: - User Reported - Default	Choose one: ○ [ ] ● 1.8%	[ ] 3
Heifer Failure to Breed Rate:	15.0%	Step 4.1
Heifer Abortion Rate:	3.3%	Step 4.2
Number of Heifers > 1 Year Needed to Produce Replacements:	37.7%	5
Heifers > 1 Year as a Percent of One Lactating Cow (excluding Dry Cows):	**43.8%**	6

DEATH RATE FOR HEIFERS > 1 YEAR (DRH) is the percent of heifers greater than one year of age that have not calved, and die annually in the herd.

HEIFER FAILURE TO BREED RATE (HFBR) is the percentage of total yearling or older heifers in the herd that either did not conceive following one or repeated breeding attempts, or conceived but lost the embryo within 40 days of conception. The value for this parameter is drawn directly from **Step 4.1.**

HEIFER ABORTION RATE (HAR) is the percentage of heifers that were successfully bred but lost their calves due to spontaneous abortion between days 41-260 post-conception. This value is brought forward from **Step 4.2.**

NUMBER OF HEIFERS > 1 YEAR NEEDED TO PRODUCE REPLACEMENTS (NH>1NPR) is the percentage of heifers relative to one lactating cow that will be needed in order to assure that the number of freshening heifers equals the number of replacements needed. This percentage equals the NUMBER OF REPLACEMENT HEIFERS NEEDED TO SUSTAIN THE HERD (NRHNSH) divided by the survival rate of heifers > 1 year (1-DRH), divided again by heifer breeding success (1-HFBR), and divided again by the the percentage of bred heifers carrying calves to term (1-HAR). For example, with a 2% heifer>1 death rate, an 18% failure to breed rate, and a 4% abortion rate, the initial pool of heifers ready for breeding must equal 60.4% of the adult cows in a herd in order to produce replacement animals equal to 46.6% of the total adult cows in a herd.

The formula for this calculation is:

$$NH > 1NPR = NRHNSH/[1-DRH]/[1-HFBR]/[1-HAR]$$

HEIFERS > 1 YEAR AS A PERCENT OF ONE LACTATION COW (H>1OLC) expresses the number of heifers older than one year as a percentage of the number of lactating cows (excluding dry cows) in a herd, via the formula:

$$H > 1OLC = \left(\frac{NH > 1NPR}{OLC \text{ as } \% \text{ ADULT COWS}} \right)$$

STEP 1.3.2. NUMBER OF LIVE HEIFERS < 1 YEAR NEEDED

A small percentage of heifers older than one year die each year, and so farmers must assure that there are enough heifers less than one year old in the herd, or accessible from outside sources, to assure an adequate supply of heifers of breeding age, taking into account death losses. This is done in **Step 1.3.2**

Step 1.3.2 Number of Live Heifers < 1 Year Needed		
Death Rate for Heifers < 1 Year: - User Reported - Default	Choose one: ○ [ ] ● 1.8%	[ ] 3
Number of Heifers < 1 Year Needed:	38.3%	5
Heifers < 1 Year as a Percent of One Lactating Cow (excluding Dry Cows):	**44.6%**	6

DEATH RATE FOR WEANED HEIFERS (DRWH) is the percent of weaned heifers less than one year old on a farm that die in a given year.

NUMBER OF HEIFERS < 1 YEAR NEEDED (NH<1N) accounts for mortality within the weaned heifer population and determines the number of heifers less than one year old necessary to meet the needs for freshening heifers to replace lactating plus dry cows that are culled or die.

The equation is:

$$NH < 1N = \left(\frac{NH > 1NPR}{(1 - DRWH)} \right)$$

HEIFERS < 1 YEAR AS A PERCENT OF ONE LACTATING COW (H<1P) is the percentage of heifers less than one year old required, expressed relative to one lactating cow, rather than all adult cows.

The formula is:

$$H<1P = HN<1N \ / \ OLC \text{ as a } \% \text{ of ADULT COWS}$$

STEP 1.3.3. NUMBER OF LIVE HEIFER CALVES THAT MUST BE BORN TO SUSTAIN HERD SIZE

Taking into account all of the above factors, the number of heifer calves that must be born to sustain the milking herd at a constant level is calculated in **Step 1.3.3**. The calves can be born on the farm or elsewhere.

Step 1.3.3 Number of Live Heifer Calves that Must be Born to Sustain Herd Size			
	Percent of Adult Cows in Herd	Percent of One Lactating Cow	Source No.
Death Rate for Unweaned Heifers:	Choose one:		
- User Reported	○		
- Default	● 7.8%		3
Number of Heifers that Need to be Born:	41.6%		5

DEATH RATE FOR UNWEANED HEIFERS (DRUH) is the percent of unweaned heifers that are born dead, die during or soon after delivery, or prior to weaning.

NUMBER OF HEIFERS THAT NEED TO BE BORN (NHNB) adjusts the number of heifer calves needed at one year of age, to take into account the death rate of unweaned heifer calves.

$$NHNB = \left(\frac{NH < 1N}{(1 - DRUH)} \right)$$

STEP 1.3.4. BULLS NEEDED FOR BREEDING

This step estimates the number of bulls needed for breeding purposes. The animals can either reside on the farm, or in the case of farms using artificial insemination (AI), the bulls are typically raised elsewhere. Many farms combine AI and natural breeding, where bulls are used to "clean up" heifers or cows that fail to conceive after multiple AI services.

Step 1.3.4 Bulls Needed for Breeding			
Number of Cows per Bull	Choose one:		
- User Reported	○		
- Default (dependent on Breeding Method chosen in Step 4):	● 40		
Bulls Needed:	2.5%	**2.5%**	7

NUMBER OF COWS PER BULL (NCB) is breeding method dependent (set in **Step 4**). Typically bulls can impregnate about 40 cows per year on farms using natural breeding methods, whereas a single bull can inseminate many times this number if the animal is used as a source of semen for AI.

BULLS NEEDED (BN) as a percent of adult cows is 1/NCB, where NCB is the number of cows that one bull can impregnate.

STEP 1.4. BODY WEIGHTS

The size of dairy animals helps determine the amount of feed intake required and waste generated on a day to day basis. Animal weights are recorded in this step in international (kg) and domestic (lb) units. The user must also specify the breed of animal in this step in order for default weights for lactating and dry cows, heifers and calves to be displayed.

Animal weights also play a role in the calculation of meat production and income from meat sales in **Step 5**.

Step 1.4 Body Weights		
Breed of Herd:	Choose Breed: Holstein	
Units of Measure:	Units of Measure: kg	
Lactating Cow Weight	Choose one:	
- User Reported	○ [ ] kg	[ ]
- Default	● 650 kg	8
Dry Cow Weight	Choose one:	
- User Reported	○ [ ] kg	[ ]
- Default	● 755 kg	8
Heifer > 1 Weight (at 18 mos.)	Choose one:	
- User Reported	○ [ ] kg	[ ]
- Default	● 437 kg	8
Calf Weight (at 7 mos.)	Choose one:	
- User Reported	○ [ ] kg	[ ]
- Default	● 153 kg	8
Full Grown Calf Weight	Choose one:	
- User Reported	○ [ ] kg	[ ]
- Default	● 700 kg	8

BREED OF HERD – current drop-down box options are Holstein, Jersey, or Crossbreed.

UNITS OF MEASURE can be chosen as International (kg) or US (pounds).

STEP 2. FACTORS DETERMINING ADULT COW CULLING AND DEATH AND DOWNER RATES

This step assumes that a given dairy farm is at a steady state in terms of the size of the milking herd. On such a farm, adult cows leaving the herd in any given year must be replaced with an equal supply of freshening heifers.

Adult cows leave dairy herds for several reasons including death, failing health that causes them to fall and become immobilized and unable to stand (i.e., a downer cow), or culling. A farmer might choose to voluntarily cull a low-producing cow to open up a spot for a heifer with superior genetics, or to accelerate the shift in the animal population toward breeds that do better on pasture.

Cows are involuntarily culled because of some recurrent or progressive health or production-related problem that renders the animal no longer profitable. **Step 2.1** provides the user a place to record the reasons leading to a decision to cull an adult cow, while **Step 2.2** covers factors leading to death or downer cow status among adult cows.

STEP 2.1. FACTORS DETERMINING CULL RATES FOR LACTATING COWS

Step 2. Factors Determining Lactating Cow Culling and Death Rates Incorporated in Step 1.2

	Scenario 1 Dairy Farm 1		
Step 2.1 Factors Determining Cull Rates for Lactating Cows			
Reason(s) for Involuntary Culling:	Default	User Reported	Reported Source
Reproductive Problems	6.2%		
Mastitis/Udder Issues	5.4%		
Lameness	3.8%		
Respiratory Problems			
Poor Production	3.8%		
Aggressiveness or Belligerence (kickers)	0.2%		
Other Diseases	0.9%		
Other Reasons	1.0%		
Total Involuntary Cull Rates:	**21.2%**	**0.0%**	
Reason(s) for Voluntary Culling:			
Genetic Improvement (cow stays in production)			
Reducing Herd Size (cow stays in production)	1.4%		
Other Reasons	1.0%		
Total Voluntary Cull Rates:	**2.4%**	**0.0%**	

Some animals are culled for what are considered "involuntary" reasons including lameness, recurrent udder infections, failure to rebreed, or poor production. Other animals may be culled "voluntarily," for reasons that are not related to any health or production-related shortcoming. "Involuntary culling" is an indicator of cow health and the presence/absence of management-related stress on animals, whereas "voluntary" culling is not.

REASON(S) FOR INVOLUNTARY CULLING (RFIC) are derived from industry surveys of the most common reasons why adult animals are culled from a herd. In the USER REPORTED column, the value in each cell is a percentage of lactating cows in the herd. The sum of all values listed in the DEFAULT and USER REPORTED columns are automatically transferred to the USER REPORTED line in **Step 1.2.1** for the INVOLUNTARY CULL RATE FOR LACTATING COWS (ICRLC).

REASONS(S) FOR VOLUNTARY CULLING (RFVC) are also derived from industry surveys of the most common reasons why adult animals are culled from a herd. As with the RFIC, the value in each cell is a percentage of lactating cows in the herd. The sum of all values listed in the DEFAULT and USER REPORTED columns are automatically transferred to the USER REPORTED line in **Step 1.2.1** for the VCRLC.

STEP 2.2. FACTORS DETERMINING DEATH AND DOWNER RATES FOR LACTATING COWS

Step 2.2 Factors Determining Death and Downer Rates for Lactating Cows			
Reason(s) & Risk Factors for Death and Downer Rates:	Default	User Reported	Reported Source
Digestive Problems	0.6%		
Mastitis/Udder Issues	0.9%		
Lameness	1.1%		
Respiratory Problems	0.6%		
Poison	0.02%		
Lack of Coordination, Depression or Other CNS	0.1%		
Calving Problems	0.9%		
Other Known Reasons	0.6%		
Unknown Reasons	0.9%		
Total Death and Downer Rate:	**5.7%**	**0.0%**	

REASONS AND RISK FACTORS FOR DEATH AND DOWNER RATES (DRRRF) can again be derived from specific farm records or from industry or USDA surveys. The values in the cells are expressed as a percent of all lactating cows in the herd. As in the case of **Step 2.1**, the total DRRRF is automatically transferred to the USER REPORTED line in **Step 1.2.1.**

STEP 3. LACTATION PROFILE

Step 3. Lactation Profile	Scenario 1 Dairy Farm 1		
Current Lactation			**Source No.**
Lactation Period:	Multiparous		
Milking Frequency:	2-X		
Days in Milk (DIM): *(Day in Lactation used to compare systems; default value is the 150th day)*	150 day in lactation		5
Milk Quality:			
- Percent Milk Protein	3.20 %		
- Percent Milk Fat:	3.70 %		
Daily Milk Production:		**Converted Values**	
Unadjusted Milk Production	Choose one:		
- User Reported	○ lb/day	0.00 kg/day	
- Default	◉ 60.0 lb/day	27.22 kg/day	4
Protein and Fat Corrected Milk (ECM) *(ECM-Energy Corrected Milk)*	61.35 lb/day	27.83 kg/day	1
- Protein Content	1.92 lbs protein	0.87 kg protein	2
- Fat Content	2.22 lbs fat	1.01 kg fat	2
Length of Lactation:	Choose one:		
- User Reported	○ days		
- Internally Calculated Based on Number of Breeding Attempts per Conception and Days Between Breeding Attempts (see Step 4)	◉ 356.5 days		3
Length of Dryoff Period:	Choose one:		
- User Reported	○ days		
- Default	◉ 57.8 days		4

The lactation profile on a dairy farm encompasses the amount of milk produced per day, milk quality in terms of fat and protein content, and the average length of lactations and dry off periods. These parameters differ markedly across farms as a function of cow breed, management strategies and intensity, and feed composition and quality. Production levels, in particular, have great influence on animal reproduction, life spans, feed intake, manure output, and the velocity at which carbon, nitrogen, and phosphorus cycle through dairy operations.

The LACATION PERIOD drop down box currently offers three choices:

- Multiparous (multiple lactations)
- First, or
- Second lactation.

On most farms, some cows will fall into each of these stages. This field is useful when studying a given group of cows, e.g., first-calf heifers. The choice in this field has no direct impact on any other step within the calculator.

The MILKIING FREQUENCY drop-down box offers three choices

- 2-X (daily)
- 3-X (daily), or
- seasonal.

Again, this parameter is for information purposes only and does not impact any other INTERNALLY CALCULATED value

DAYS IN MILK (DIM) specifies the stage or point in a lactation for which production and feed intake estimates are made and incorporated in a **SOG** application. It is the number of days, on average, that a cow, or set of cows have been milking. Cow nutritional needs, feed intakes, and waste generation vary over the course of a lactation, and hence, it is desirable when comparing operations and management scenarios to base estimates on the same, or similar DAYS IN MILK. The selection here has no impact on other steps in the calculator.

The PERCENT MILK FAT and the PERCENT MILK PROTEIN are two, basic indicators of MILK QUALITY that are routinely monitored on the farm and at the milk plant.

Daily milk production is the average pounds of milk produced in a day over a lactation by an average lactating cow. It can be measured in two ways: UNADJUSTED MILK, based on the gross weight of the product and ENERGY CORRECTED MILK (ECM).

ECM is typically preferred by research scientists as a measure of milk production since it takes into account both the quantity of milk produced by a cow and the quality of the milk. The formula for calculating ENERGY CORRECTED MILK (ECM) is derived from an Extension Service fact sheet (**http://www.extension.org/faq/27579**) and is consistent with the equation recommended by the National Research Council.

The ECM formula is:

$$ECM = (UMPD \times 0.323) + (7.13 \times \text{Protein Content}) + (12.82 \times \text{Fat Content})$$

LENGTH OF LACTATION (LOL) is a key parameter that is determined by a number of factors. The main factor impacting average length of lactation is reproductive performance within the milking herd. The key parameters driving reproductive performance are covered in **Step 4** and include the average number of breedings required per conception, the average number of days between breeding attempts, the success rate following conception, and the number of days in the dryoff period between the end of a lactation and the birth of the next calf (see **Step 4** for details).

The LENGTH OF LACTATION can be internally calculated as the sum of a set of time periods beginning with the average number of days from calving to the first attempt at re-breeding. If the animal conceives at the first breeding attempt, the second time period during a lactation is about 220 days, or the typical gestation period (about 280 days) minus a standard dryoff period (60 days).

But not all breeding attempts result in a conception, and for those that do not, additional days must be added to the LOL to account for the time it takes to determine if the cow is pregnant, and if it is not, to rebreed her. This period of time is referred to herein as NUMBER OF DAYS BETWEEN BREEDING ATTEMPTS (NDBBA).

Some successful conceptions do not result in the birth of a calf because of embryo loss or spontaneous abortion. These successful breeding attempts that do not result in the birth of a calf have a significant impact on the average number of days between breeding attempts across a herd, because so many more days pass by before a farmer will discover that a cow that previously was found to be pregnant no longer is. Because these factors increase the average number of days between breeding attempts, they also increase the length of the average lactation, as determined in **Step 4.**

LOL can be USER REPORTED, drawing on farm specific or survey data, or INTERNALLY CALCULATED using the formula:

$$LOL = NDCFBA + [(ABAPC - 1) \times NDBBA] + (GP - LDP)$$

Where:
NDCFBA is the NUMBER OF DAYS FROM CALVING TO FIRST BREEDING ATTEMPT
ABAPC is the AVERAGE BREEDING ATTEMPTS PER CONCEPTION TO TERM
NDBBA is the NUMBER OF DAYS BETWEEN BREEDING ATTEMPTS
GP is the GESTATIONAL PERIOD
LDP is the LENGTH OF THE DRYOFF PERIOD

An example follows -- Suppose a Holstein cow is bred the first time at 60 DAYS IN MILK, and conceives after three breeding attempts. Further assume there were 50 days on average between breeding attempts, a 60 day dryoff period, and an average 282 day gestation period. Under these circumstances, the average length of lactation would be equal to: 60 + (3-1)*50 + (282-60) = 382 days.

LENGTH OF DRY OFF PERIOD (LDP) is the average number of days between the end of a previous lactation and the birth of the next calf. Most farmers typically strive for a dryoff period of about 60 days.

STEP 4. BREEDING PERFORMANCE, COW HEALTH, AND LONGEVITY

Several key indicators of cow health and reproductive performance are recorded or calculated in **Step 4.** The breeding success of high-production dairy animals has declined sharply over the last half-century, as measured by the number of breeding attempts necessary to produce a successful conception and birth of a calf. As the average number of breeding attempts per birth has risen, so too has the average length of lactations. This, in turn, has reduced the average number of lactations during a cow's productive life and the number of calves born to each cow.

Values recorded or calculated in **Step 4** are used in **Step 3** in estimating the average length of lactations and in **Step 5**, where the total milk and meat produced during a cow's life are calculated.

MODELING REPRODUCTIVE PERFORMANCE

Multiple factors determine the average number of times a cow must be bred to produce a calf, and the average number of days between breeding attempts. These two key indicators of the performance of a farm's breeding and cow health programs can be calculated, or at least approximated, at the end of any given year from records that are routinely kept. A user of **SOG** can easily calculate the average length of lactation on the farm from cow-specific records on:

- the date a given cow had her calf, and
- the date the cow was removed from the milking herd.

For farms using artificial insemination, records will be accessible regarding how many times cows were served, allowing the user to calculate the average number of services per freshening cow. With this information, the average number of days between breeding attempts can be estimated.

On farms using natural breeding, it is harder to accurately estimate the number of services per conception, although records will often exist, or can be estimated by farmers and/or workers, on the number of times a cow displayed estrus (a heat cycle) and was moved into the breeding pool of cows. The average length of lactation will be known, and the average number of breedings per freshening cow can be approximated. These two variables can then be used to estimate the average days between breeding attempts.

Still, much of the more detailed information needed to explain the performance of a farm's breeding program will not be available to **SOG** users or farmers. For example, in the case of a cow that was bred but returns to heat, the farmer will not know whether that cow failed to conceive, or conceived but experienced a loss of the embryo. The longer the time delay in a cow returning to heat after being bred, the higher the odds that:

- the cow conceived but lost the calf,
- the cow did not conceive, but experienced a weak estrus cycle that was missed by the farmer or workers managing the breeding program, or
- the cow did not conceive, had a normal estrus cycle, but the cycle was missed by the farmer or workers.

The key parameters driving reproductive performance on dairy farms are included in **Steps 4.1** to **4.3** below. Users will need to add values for these variables from their records, surveys, published research, experience, or other sources, or use DEFAULT values. The last parameter in **Step 4.1**, NUMBER OF DAYS BETWEEN BREEDING ATTEMPTS, can also be INTERNALLY CALCULATED, if the user can provide or approximate the necessary data in **Step 4.2**, which addresses the impacts of various possible outcomes of previous breeding attempts.

Step 4.2 is designed to provide insights into how the outcomes of previous breeding attempts determine the average days between breeding attempts across all outcomes. No farmer, veterinarian, or dairy scientist will have definitive information to accurately establish the parameter values in **Step 4.2**. Estimates will have to be made based on experience, surveys, and published studies on reproductive performance across breeds and management systems. Several studies have produced estimates of:

- The percent of breeding attempts that are unsuccessful and successful (i.e. produce a conception);
- The percent of conceptions that end with embryo loss in the first 40 days; and,
- The percent of conceptions that end with a spontaneous abortion during days 41-260. (Conceptions going beyond 260 days are regarded as full term and generally result in the birth of a calf [alive or dead] and the cow entering the milking herd.)

By coupling estimates of the frequency of these outcomes from a previous breeding with the average days between breedings in each of these circumstances, an estimate can be made of the average days between breedings, taking into account the diversity of outcomes reflected in **Step 4.2.**

For some users, this detailed information on breeding performance may not be accessible or of interest. As long as all parameters are filled out in **Step 4.1, Step 4.2** can be skipped.

Step 4. Breeding Performance, Cow Health and Longevity	
	Scenario 1 **Dairy Farm 1**
Method of Breeding:	○ Bull ○ Artificial Insemination (AI) with Synchronization ● Artificial Insemination (AI) without Synchronization

Step 4 begins with a place to record the METHOD OF BREEDING (MOB): bull, artificial insemination (AI) with synchronization, and AI without synchronization. Conception and abortion rates vary significantly by breeding method, and hence the importance of designating the breeding method associated with a given scenario.

STEP 4.1. REPRODUCTIVE PERFORMANCE

Step 4.1 Reproductive Performance	Adult Cows	Heifers (1st time breeders)	Source No.
Age of Heifer at First Breeding Attempt (mos.): - User Reported - Default	N/A	Choose one: ○ [ ] ● 12.65	[ ] [ ]
Number of Days from Calving to First Breeding Attempt: - User Reported - Default	Choose one: ○ [ ] ● 60	N/A	[ ] [ ]
Failure to Breed Rate: - User Reported - Default	Choose one: ○ [ ] ● 45%	Choose one: ○ [ ] ● 15.0%	[ ] [ ]
Average Breeding Attempts per Conception to Term: - User Reported - Default	Choose one: ○ [ ] ● 2.8	Choose one: ○ [ ] ● 2.8	[ ] [ ]
Number of Days between Breeding Attempts: - User Reported - Default -Internally Calculated (based on outcome of previous breeding; see next section)	Choose one: ○ [ ] ○ 36.0 ● 40.2	Choose one: ○ [ ] ○ 36.0 ● 39.4	[ ] [ ] 1

AGE OF HEIFER AT FIRST BREEDING ATTEMPT IN MONTHS (AHFBA) is typically around one year old. The trend in recent years has been toward earlier breeding of heifers, which lowers the cost of replacements but can also adversely impact cow health, production, and longevity.

NUMBER OF DAYS FROM CALVING TO FIRST BREEDING ATTEMPT (NDCFBA) is typically around 60 days on most dairy farms and tends to not vary significantly across farms.

FAILURE TO BREED RATED (FBR) is the percent of cows served that do not conceive.

AVERAGE BREEDING ATTEMPTS PER CONCEPTION TO TERM (ABAPC) is the average number of breeding attempts required for cows to conceive. This parameter has important implications for labor costs and the average length of lactations.

NUMBER OF DAYS BETWEEN BREEDING ATTEMPTS (NDBBA) is the average time period between a breeding attempt, the discovery that the animal is not pregnant, and the scheduling of a rebreeding attempt. This time period is a complex function of:

- How farmers detect heat (estrus) and check for pregnancy,
- The method of breeding used,
- The protocols used for scheduling subsequent breeding attempts and the number of breeding attempts a farmer is willing to make before retiring a cow because of failure to rebreed,

- The percentage of cows that conceive but suffer embryo loss within 40 days of conception, and
- The percentage of cows that conceive but lose their calf to spontaneous abortion.

The time periods between breeding attempts vary significantly as a function of the above outcomes of the previous breeding. The shortest time period occurs in instances when the cow did not conceive and the farmer determined that the cow was open and returned the cow to the breeding pool on a timely basis. If a cow conceived but loses the embryo at say 20 days, she will cycle back into heat, but not until several days after a cow that was bred on the same day, but did not conceive.

Accordingly, the value for the NUMBER OF DAYS BETWEEN BREEDING ATTEMPTS (NDBBA) parameter is the weighted average of the days between breeding attempts in three cases:

- No conception in the previous breeding, so the cow would be expected to come back into heat and be rebred in the next 1-2 estrus cycles;
- Conception leading to embryo loss in the first 40 days; and
- Conception leading to a spontaneous abortion.

The INTERNALLY CALCULATED value of this parameter is a weighted average of the days between breedings when there was no conception, and the days between breedings when a cow conceived but lost the embryo or fetus to spontaneous abortion. The estimated days between breedings in each of these cases is multiplied by the percent of cows falling in these two categories. This number of days is then multiplied by a factor that forces the sum of the percentages in the two categories to add up to one, a requirement when calculating a weighted average between two or more groups of animals.

$$\mathrm{NDBBA} = \frac{1}{\mathrm{PCSNC} + \mathrm{PCFT}} \times \left(\left(\mathrm{PCSNC} \times \mathrm{DNBA} \right) + \left(\mathrm{PCFT} \times \mathrm{ADBBA} \right) \right)$$

Where:
PCSNC = PERCENT OF COWS SERVED BUT NO CONCEPTION
PCFT is the PERCENT OF COWS FAILING TO GO TO TERM This sum represents the total percent of cows failing to produce a calf.
DNBA is the AVERAGE DAYS TO NEXT BREEDING ATTEMPT (Step 4.2)for cows that did not conceive.
ADBBA is the AVERAGE DAYS BETWEEN BREEDING ATTEMPTS (Step 4.2) for animals that conceived but lost the embryo or fetus. This value is itself a weighted average between the number of days in the event of embryo loss and the number of days when a spontaneous abortion occurs.

STEP 4.2. OUTCOME OF PREVIOUS BREEDING

Step 4.2 can be skipped if the user lacks access to information on the outcomes of previous breeding attempts, although all parameters in **Step 4.1** above must be completed for other parts of the calculator to work.

Step 4.2 Outcome of Previous Breeding	Adult Cows	Heifers (1st time breeders)	Source No.
Unsuccessful Breeding Attempts:			
Percent of Cows (served but no conception)	Choose one:	Choose one:	
- User Reported	○	○	
- Default	◉ 50.0%	◉ 50.0%	2
Average Days to Next Breeding Attempt	Choose one:	Choose one:	
- User Reported	○	○	
- Default	◉ 30	◉ 30	
Successful Breeding Attempts Leading to Embryonic Loss or Abortion:			
Embryonic Loss Rate (1-40 days)			
Percent of Cows Served	Choose one:	Choose one:	
- User Reported	○	○	
- Default	◉ 13.0%	◉ 13.0%	2
Average Days to Next Breeding Attempt	Choose one:	Choose one:	
- User Reported	○	○	
- Default	◉ 60	◉ 60	
Spontaneous Abortion Rate (41 - 260 days)			
Percent of Cows Served	Choose one:	Choose one:	
- User Reported	○	○	
- Default	◉ 4.2%	◉ 3.3%	2
Average Days to Next Breeding Attempt	Choose one:	Choose one:	
- User Reported	○	○	
- Default	◉ 100	◉ 100	
Total Lost Conceptions			
Percent of Conceptions Failing to go to Term:	17.2%	16.3%	
Average Days Between Breeding Attempts:	69.8	68.1	

Step 4.2 divides all previous breeding attempts into two categories: cows that did not conceive (i.e., unsuccessful breeding attempts), and cows that did conceive. It furthermore records information on possible outcomes in those cases where a cow did conceive. The last two rows in **Step 4.2** calculate the percent of lost conceptions and estimate, using a weighted average formula, the average number of days between breeding attempts for the group of animals that conceived but lost the calf prior to day 260th day of the pregnancy.

Unsuccessful breeding attempts are breeding attempts that fail to result in a conception.

PERCENT OF COWS SERVED BUT NO CONCEPTION (PCSNC) is the percentage of cows served on a given day, or during a given time period, that did not conceive.

AVERAGE DAYS TO NEXT BREEDING ATTEMPT (DNBA) is the average number of days that elapse between a previous breeding attempt and the next service. For cows in this category that go into a normal estrus cycle and are recognized as in heat and rebreed, the average number of days between breedings will be around 24-26. Some of these cows may go into a weak estrus cycle that is missed, resulting in 42-48 days between breeding attempts. An average of around 30 days is common on well managed farms.

Successful breeding attempts leading to embryonic loss or abortion covers animals that did conceive but do not carry a calf to term, resulting in no birth event, nor freshening and movement of the cow into the milking herd.

EMBRYONIC LOSS RATE (1 - 40 DAYS)
is a standard measure of reproductive outcomes and encompasses conceptions that are successful, but which are naturally terminated within 40 days because of injury or some other lactating cow health problem or source of stress.

PERCENT OF COWS EXPERIENCING EMBRYONIC LOSS (PELR) covers animals that lose their calves between days 1 and 40 of their pregnancy.

Within the step covering embryonic loss, AVERAGE DAYS TO NEXT BREEDING ATTEMPT (ELDNBA) is the average number of days between breeding attempts for those cows that conceived, but lost their calf in the first 40 days. The cows in this class will have longer time periods between breeding attempts, compared to cows that did not conceive and would be expected to return to estrus in 24-26 days. Suppose the average instance of embryonic loss on a farm occurs at day 12 of pregnancy, this would result in an expected 42 days (30+12) days between breeding attempts for this cohort of cows.

SPONTANEOUS ABORTION RATE (41-260 DAYS)
is another standard measure of reproductive outcomes and entails loss of the developing calf between days 41 and 260 of pregnancy.

PERCENT OF COWS SERVED EXPERIENCING SPONTANEOUS ABORTION (PSAR) is the percent of cows that conceived, but lost their calf to a spontaneous abortion.

Within the step covering spontaneous abortions, AVERAGE DAYS TO NEXT BREEDING ATTEMPT (SADNBA) is the average number of days between breeding attempts for those cows that conceived, but lost their calf between days 41 and 260 to spontaneous abortion. The cows in this class will have markedly longer time periods between breeding attempts, compared to cows that did not conceive or experienced embryonic loss. Suppose that the spontaneous abortions on a given farm occur, on average, at day 120 of the pregnancy. This would result in an expected, average days between breeding attempts of about 150 days (30+120). A portion of the cows in this category are likely to be culled from herds, once milk production drops below the level regarded as profitable by the farmer.

TOTAL LOST CONCEPTIONS
is where the combined impact of embryonic loss and spontaneous abortions are calculated, based on the information in **Step 4.2.**

PERCENT OF CONCEPTIONS FAILING TO GO TO TERM (PCFT) is the embryonic loss rate plus the spontaneous abortion rate, or PELR+PSAR.

AVERAGE DAYS BETWEEN BREEDING ATTEMPTS (ADBBA) is a weighted-average of the days between breeding attempts for conceptions that end with embryonic loss and those that end as a result of spontaneous abortion. The weights are the percentages of conceptions resulting in each of these two outcomes (embryonic loss and spontaneous abortions), adjusted to add to one.

The formula to calculate this parameter is:

$$\mathrm{ADBBA} = \frac{1}{\mathrm{PCFT}} \times \left(\left(\mathrm{PELR} \times \mathrm{ELDNBA} \right) + \left(\mathrm{PSAR} \text{ x } \mathrm{SADNBA} \right) \right)$$

Where:
(1/PCFT) is an adjustment factor needed to assure that the percentages in the weighted average formula add up to one (PCFT is the PERCENT OF CONCEPTIONS FAILING TO GO TO TERM).
PELR is the EMBRYONIC LOSS RATE.
ELDNBA is the AVERAGE DAYS TO NEXT BREEDING ATTEMPT in the event of embryonic loss.
PSAR is the SPONTANEOUS ABORTION RATE.
SADNBA is the AVERAGE DAYS TO NEXT BREEDING ATTEMPT in the case of cows losing calves to spontaneous abortion.

Step 4.3 Conceptions Going Full Term				
Calving Interval:	Choose one:			
- User Reported	○		days	
- Internally Calculated	●	414	days	3
Gestation Period:		282	day:	
Age of Heifer at First Birthing (months):	Choose one:			
- User Reported	○		months	
- Default	○	25.2	months	4
- Internally Calculated	●	24.3	months	4
Calf Production per Lactation:				
Percent of Cows that have Live Births		88.0%		
Percent of Cows that Produce Heifer Calves		50.8%		5
Percent of Cows that Produce Bull Calves		49.2%		5
Number of Heifer Calves Born		0.45	heifer calves	
Number of Bull Calves Born		0.43	bull calves	
Calf Production in Productive Life:				
Number of Heifer Calves		0.89	heifer calves	6
Number of Bull Calves		0.87	bull calves	6
Total Number of Calves		1.76	total	

STEP 4.3. CONCEPTIONS GOING FULL TERM

The outcome of previous breeding attempts help determine another key indicator of cow health and reproductive performance e.g. the CALVING INTERVAL (CI). This interval is the number of days between the birth of a calf and the cow entering the milking herd, and the birth of a subsequent calf, the event that allows a bred cow to re-enter the milking herd after a dryoff period.

CALVING INTERVAL (CI) is the sum of the LOL (LENGTH OF LACTATION in days, from **Step 3**) and LDP (LENGTH OF DRYOFF PERIOD in days, from **Step 3**). Historically, dairy farmers have sought to manage their herds to produce a 365 day calving interval composed of 305 day lactations and 60 day dryoff periods.

The formula is:

$$CI = LOL + LDP$$

GESTATION PERIOD (GP) is the number of days from conception to birth for conceptions that go full term resulting in the birth of a calf. For Holsteins, the average GESTATION PERIOD is typically assumed to be 282 days. This time period is used as the default value for all breeds.

AGE OF HEIFER AT FIRST BIRTHING IN MONTHS (AHFB) is the age of a heifer on the day her first calf is born. This time period is a function of the AGE OF HEIFER AT FIRST BREEDING ATTEMPT, the percent that conceive on the first attempt, the average NUMBER OF DAYS BETWEEN BREEDING ATTEMPTS, and the percentage that conceive as a result of the second and any subsequent attempts. This parameter plays a role in calculating the overall longevity of lactating dairy animals.

The formula for the INTERNALLY CALCULATED value of this parameter is:

$$AHFB = AHFBA + \left(\frac{(ABAPC_{(Heifers)} - 1) \times NDBBA_{(Heifers)}}{30.4} \right) + \left(\frac{GP}{30.4} \right)$$

Where:
AHFBA is the AGE OF HEIFER AT FIRST BREEDING ATTEMPT(months).
ABAPC is the AVERAGE BREEDING ATTEMPTS PER CONCEPTION TO TERM for heifers.
NDBBA is the NUMBER OF DAYS FROM CALVING TO FIRST BREEDING for heifers.
GP is the GESTATION PERIOD.

Important Note -- 30.4 is the average number of days in a month, and is used to convert parameters expressed in days to months.

CALF PRODUCTION PER LACTATION (CPLACT) calculates the average number of heifer and bull calves born based on cow conception rates and standard estimates of the percent of live births producing a heifer or a bull calf. These parameters are used in calculating the meat production associated with a cow's productive life in **Step 5**.

CALF PRODUCTION IN PRODUCTIVE LIFE (CPPL) is the number of live calves produced by a lactating dairy animal during her productive life. It is projected based on number of heifer and bull calves born per calving, multiplied by the number of expected lactations in a cow's productive life (from **Step 4.4**).

STEP 4.4. COW HEALTH AND LONGEVITY

Step 4.4 Cow Health and Longevity		
Days in Lactation with Diverted Milk: - User Reported (from Worksheet A below) - Default	Choose one: ○ 5.0 days ◉ 5.0 days	see below
Age of Cow at End of Productive Life: - User Reported - Internally Calculated	Choose one: ○ years ◉ 4.28 years	7
Number of Years Cow is Productive:	2.26 years	8
Number of Lactations in Productive Life: - User Reported (from Worksheet B below)	2 lactations	see below

DAYS IN LACTATION WITH DIVERTED MILK (DLDM) is the average number of days in a lactation during which milk is diverted from sale because of mandatory diversion requirements on animal drug labels, milk quality problems, or the need for colostrums to get just-born calves off to a healthy start, or organic milk needed to raise organic calves to weaing. This variable is provided for users that want to differentiate between total milk production and marketable milk production.

The USER REPORTED value for DLDM comes automatically from **Worksheet A**, which appears directly below the main table in **Step 4**. In this worksheet, the user can identify specific reasons for diverting milk from production and estimate the average number of days of diverted milk during a lactation from multiple causes. See **Worksheet A** below for details.

AGE OF COW AT END OF PRODUCTIVE LIFE (ACEPL) is expressed in years and is the basic measure of cow longevity. It is also a key indicator of cow health. The age of a cow at the end of her productive life is the sum of her age at first breeding, her NUMBER OF LACTATIONS multiplied by AVERAGE LENGTH OF LACTATION, and the average DAYS IN DRYOFF periods multiplied by her NUMBER OF LACTATIONS minus one (since there is typically no dryoff period associated with a cow's last lactation).

The length of a cow's productive life is the cumulative effect of average daily milk production, the length of lactations, feed quality, animal health programs, breeding methods, and living conditions.

The formula used in the internal calculation of this parameter is:

$$\text{ACEPL} = \frac{((\text{AHFB} \times 30.4) + (\text{LOL} \times \text{NOL}) + ((\text{NOL - 1}) \times \text{LDP}))}{365.25}$$

Where:
AHFB is the AGE AT FIRST BIRTHING in months (converted to days by multiplying by 30.4).
LOL is average LENGTH OF LACTATION in days.
NOL is the NUMBER OF LACTATIONS in a cow's productive life.
LDP is the LENGTH OF DRYOFF PERIOD in days.

NUMBER OF YEARS COW IS PRODUCTIVE (#YCP) is the time period from the birth of a first calf to the end of the cow's productive life (i.e., the day the cow is moved out of the milking herd for the last time).

NUMBER OF LACTATIONS IN PRODUCTIVE LIFE (NOL) is a key variable that drives many other calculations. It must be USER REPORTED based on information about the longevity of cows in a milking herd. **Worksheet B**, also below **Step 4**, is provided to assist the user in estimating the average number of lactations in a cow's productive life. The calculated values for each scenario are automatically inserted into the NOL cells in **Step 4.4.**

WORKSHEET A FOR STEP 4.4. – DAYS IN DIVERTED MILK

Worksheet A for Step 4.4 -- Estimating the Average Number of Days in a Lactation with Diverted Milk in the Four Scenarios

	Reason for Diverted Milk Days --						
	Clostrum Post-Calving	Hold/Divert Milk Post Drug Treatment per Label	High SSC; Farmer Diverted	High SCC in Load, Milk Diverted	Antibiotics in Load, Milk Diverted	Sum of Five Reasons	Sum of Five Reasons or Enter User Reported Total
Number of Days in Diverted Milk for Scenario 1						0	5
Number of Days in Diverted Milk for Scenario 2						0	5
Number of Days in Diverted Milk for Scenario 3						0	5
Number of Days in Diverted Milk for Scenario 4						0	5

Worksheet A is provided to assist the user in determining how many DAYS a cow spends IN DIVERTED MILK from production during a lactation. Several reasons contribute to milk diversion, five of which are listed in the worksheet. For each reason, the user can enter the average number of days that milk is diverted during a typical lactation. The total number of days for each scenario (far right column in worksheet) is automatically transferred to the USER REPORTED line under DAYS OF DIVERTED MILK in **Step 4.4**. If a user does not know the specific reasons why milk was diverted, but knows the total number of days on average per lactating cow that milk was diverted, place this number of days in the last column. Otherwise, DEFAULT values can be incorporated in applications of the calculator.

WORKSHEET B FOR STEP 4.4. – NUMBER OF LACTATIONS

Worksheet B is provided to allow users to estimate the number of lactations a cow has during her productive life, based on herd averages. There are seven columns designating the percent of cows in a herd that have one, two, three, and up to seven or more lactations over its productive life. If known,

Worksheet B for Step 4.4 -- Estimating the Average Number of Lactations Over a Cow's Productive Life in the Four Scenarios (see notes)										
	Percent of Cows in the Herd by Lifetime Number of Lactations --							Calculated Average Number of Lactations	Sum of Percents (must equal 100%)	Calculated Average Number of Lactations or Enter User Reported Value
	One	Two	Three	Four	Five	Six	Seven or More*			
Percent of Cows for Scenario 1								0	0%	2
Percent of Cows for Scenario 2								0	0%	2
Percent of Cows for Scenario 3								0	0%	2
Percent of Cows for Scenario 4								0	0%	2

the user can specify these percentages based on farm records or other data.

The column CALCULATED AVERAGE NUMBER OF LACTATIONS is the weighted average of the seven previous columns, weighted by the percent of cows in each column. In the case of cows milking over seven or more lactations, an average of eight lactations is used in the weighted average formula. These values are automatically transferred to the CALCULATED AVERAGE NUMBER OF LACTATIONS OR ENTER USER REPORTED VALUE column. The value in this column is automatically inserted in the USER REPORTED box in **Step 4.4** for the variable NUMBER OF LACTATIONS IN PRODUCTIVE LIFE.

If a user does not have the data required to calculate AVERAGE NUMBER OF LACTATIONS using this worksheet, replace this parameter with the best estimate or a default value in the CALCUATED AVERAGE NUMBER OF LACTATIONS OR ENTER USER REPORTED VALUE column. **The calculator will not run correctly without a value for this parameter.**

STEP 5. TOTAL MILK AND MEAT PRODUCTION OF A LACTATING COW

The purpose of **Step 5** is to estimate total milk and meat production associated with the life of a single lactating cow. The quantities of meat and milk produced over the cow's life are expressed in **Steps 5.1** and **5.2**, both as simple totals and per year of life. **Steps 5.3, 5.4,** and **5.5** convert the volumes of meat and milk produced to estimates of revenue to the farmer, and in **Step 5.6**, the total revenue generated by the average cow on an annual basis is reported.

STEP 5.1. MILK PRODUCTION

Step 5. Total Milk and Meat Production of a Lactating Cow					
	Scenario 1 Dairy Farm 1				
Step 5.1 Milk Production					
Total Milk Production in a Cow's Productive Life:			**Converted Values**		**Source No.**
Unadjusted Milk Production	42,783	lbs	19,406	kgs	1
Energy Corrected Milk (ECM) Production	43,874	lbs	19,901	kgs	1
Age of Cow at End of Productive Life (years):	4.28	years			Step 4
Average Milk Production per Year of Life:					
Unadjusted Milk Production	9,984	lb/yr	4,529	kg/yr	2
Energy Corrected Milk Production	10,239	lb/yr	4,644	kg/yr	2

TOTAL MILK PRODUCTION IN A COW'S LIFE (TMPCL) is the average pounds of milk produced per day, multiplied by the average LENGTH OF LACTATION (LOL), multiplied by the average NUMBER OF LACTATIONS (NOL). It is expressed as pounds or kilograms of UNADJUSTED MILK and ENERGY CORRECTED MILK (ECM, see **Step 3** for the calculation of ECM milk).

The equation is:

$$TMPCL = DMP \times LOL \times NOL$$

Where:
DMP is the DAILY MILK PRODUCTION for either UNADJUSTED MILK or ECM respectively
LOL is the LENGTH OF LACTATION
NOL is the NUMBER OF LACTATIONS

AGE OF COW AT END OF PRODUCTIVE LIFE (ACEPL) is from **Step 4.4** and expressed in years.

AVERAGE MILK PRODUCTION PER YEAR OF LIFE (AMPYL) is total lifetime milk production (unadjusted and ECM) divided by the cow's age at the end of life (in years).

$$AMPYL = TMPCL / ACEPL$$

STEP 5.2. MEAT PRODUCTION

Step 5.2 Meat Production					
Annual Calf Production during a Cow's Life:					
Number of Heifer Calves	0.21	heifers/year			3
Number of Bull Calves	0.20	bulls/year			3
Total Calves	0.41	calves/year			
Meat Production from Cow at Slaughter:			**Converted Values**		
Death and Downer Rate	5.7%				Step 2.2
Portion of Cow Available for Slaughter (live weight)	1,351	lbs	613	kgs	9
Cow Dressing Rate	50%				
Carcass Weight	676	lbs	306	kgs	
Meat Production from Calves at Slaughter:					
Average Weight of Grown Calf at Slaughter	1,543	lbs	700	kgs	Step 1
Full Grown Calf Dressing Rate	58%				
Carcass Weight	895	lbs	406	kgs	
Total Meat Associated with Cow's Life:	**2,251**	**lbs**	**1,021**	**kgs**	

Each lactating cow contributes to the meat supply through the birth of calves, and at the end of her life, when the cow is sent to slaughter. The calculations in **Step 5.2** require either data or assumptions on the cow's weight at the time of slaughter and dressing percentage (percent of total carcass weight that is marketable meat), as well as the number of calves born and raised to a typical slaughter weight.

On most farms, a significant share of heifer calves are likely to be bred and used for replacements, so they will not be slaughtered at approximately 16 months old, as would be the case for animals not retained in the dairy herd. Still, the birth of each heifer calf raised as a replacement does generate approximately 1,000-1,500 pounds of animal that will eventually be slaughtered.

Some calves might be raised to slaughter weight on another farm, but this does not substantially impact the meat produced by its mother, the feed needed to bring the calves to slaughter weight, or their production of manure, urine, and greenhouse gases. The occasional practice of killing bull calves soon after birth would, however, obviously reduce the pounds of meat stemming from a given cow's offspring, as well as the quantity of feed consumed and wastes generated by the calf. This industry practice is not taken into account, and therefore estimates of meat production from bull calves are overestimated to an unknown degree.

ANNUAL CALF PRODUCTION DURING A COW'S LIFE (ACPCL) is the number of heifer or bull calves, divided by the years of life.

PORTION OF COW AVAILABLE FOR SLAUGHTER (PCAS) is the average portion of lactataing cows that survive to be culled. Cows that are removed from the herd from death or downer status are not slaughtered for meat production and therefore must be taken out of the equation. This is accomplished by taking the live weight of a lactating cow that is to be slaughtered, multiplied by the overall survival rate of cows being culled.

$$PCAS = BW_{LACTATING\ COW} \times (1\text{-}DRRRF_{LACTATING\ COW})$$

Where:

BW is BODYWEIGHT of a lactating cow

DRRRF is the DEATH AND DOWNER RATE for lactating cows

MEAT PRODUCTION FROM CALVES IN A COW'S LIFE (MPCCL) is the expected live weight of a calf at slaughter, multiplied by the number of calves born in a cow's life, multiplied by the dressing percentage.

STEP 5.3. REVENUE FROM MILK PRODUCTION

Step 5.3 Revenue from Milk Production		
Price per Pound of Milk: - User Reported - Default	Choose one: ○ [ ] ◉ $ 0.13	 [ ] 4
Milk Revenue per Year of Life: Unadjusted Milk Production (lb) Energy Corrected Milk Production (lb)	 $ 1,252 per year $ 1,284 per year	 2 2

PRICE PER POUND OF MILK (PPM) is the dollars received by the farmer per hundredweight of unadjusted milk placed on the truck divided by 100. Unless a farmer is working under a contract to a dairy processor, the open-market price of milk can be extremely variable, fluctuating up or down by 50% or more several times in a typical decade.

MILK REVENUE PER YEAR OF LIFE (MiRYOL) takes into consideration the milk diverted from production. It is the PRICE PER POUND OF MILK (PPM) times the AVERAGE MILK PRODUCTION (UNADJUSTED and ECM), the LENGTH OF LACTATION minus DAYS OF DIVERTED MILK, times the NUMBER OF LACTATIONS, divided by the YEARS OF LIFE.

MiRYOL = PPM x DMP x (LOL - DDM) x NOL / ACEPL

Step 5.4 Revenue from Animals Sold for Slaughter		
Meat Revenue Based on Calf Sales or Slaughter:	○ Sell at Weaning, skip to Step 5.5 ◉ Raise to Slaughter, continue	
Price per Pound for Cow (live weight): - User Reported - Default	Choose one: ○ $ - ◉ $ 0.25	
Price per Pound for Calf (live weight): - User Reported - Default	Choose one: ○ $ - ◉ $ 0.85	
Meat Revenue per Year of Life: - Cow - Heifers >1 that Fail to Breed - Bull and Heifer Calves **Total Revenue from Meat**	 $ 78.84 per year $ 5.91 per year $ 538.79 per year **$ 623.55** per year	 5 6 7

STEP 5.4. REVENUE FROM ANIMALS SOLD FOR SLAUGHTER

Dairy farmers generate revenue from calves through sales soon after birth or by raising the animals to slaughter weight. Users must choose one of these two options at the beginning of **Step 5.4**, MEAT REVENUE BASED ON CALF SALES OR SLAUGHTER (MRCSS). Throughout this section, users can rely on DEFAULT values or regional or farm-specific data on prices, animal weights, and dressing percentages.

PRICE PER POUND FOR COW (PPP_{Cow}) is the average price paid to the farmer for dairy animals sold on a live-weight basis.

PRICE PER POUND FOR CALF (PPP_{Calf}) is the average price paid for calves sold on a live-weight basis.

MEAT REVENUE PER YEAR OF LIFE (MeRYOL) is the pounds of meat sold multiplied by the applicable price per pound, divided by the years of life, and then added together across the three classes of animals: cows, heifers that fail to bred, and calves. **Version 1.1 of SOG** does not project or report meat sales from adult bulls used for breeding.

STEP 5.5. REVENUE FROM CALF SALES

Step 5.5 Revenue from Calf Sales			
Market Value of Heifer Calves:	Choose one:		
- User Reported	○	$ -	
- Default	●	$ 150.00	
Market Value of Bull Calves:	Choose one:		
- User Reported	○	$ -	
- Default	●	$ 75.00	
Revenue from Calves Sold:			
- Heifers		$ - heifers/year	8
- Bulls		$ - bulls/year	8
Total Revenue from Calf Sales		**$ -** calves/year	
Step 5.6 Total Revenue per Year of Life		**$ 1,908**	

MARKET VALUE OF HEIFER CALVES (MVHC) is the price for a heifer calf sold on the open market. Most heifers sold as calves are raised in the hope that they will be bred and used to meet demand for freshening heifers.

MARKET VALUE OF BULL CALVES (MVBC) is the price paid for bull calves, most of which are raised for meat.

REVENUE FROM CALVES SOLD (RCS) is the number of heifer and bull calves sold during a cow's productive life, multiplied by the average price paid per animal, and then divided by the cow's years of life.

STEP 5.6. TOTAL REVENUE PER YEAR OF LIFE

Step 5.6 presents the TOTAL REVENUE PER YEAR OF LIFE (TRYOL). It which is the sum of revenue from milk sales, revenue from the sale of the cow, revenue from the sale of calves for slaughter or sale as calves, divided by the years of life.

STEP 6. TOTAL DRY MATTER INTAKE PER MILKING COW

The pounds of DRY MATTER INTAKE (DMI) consumed on a daily basis by a lactating cow is a universal measure of total feed intake. Dairy scientists project the DMI required in order to meet an animal's nutritional needs based on the size of a cow, the animal's breed and condition, milk production levels, milk fat and protein content, energy expenditures, if any, walking to pasture, and the energy level, nutritional content, and palatability of the feed in the cow's daily ration.

Dairy scientists use a variety of models to project daily DMI needs. This key variable determines the total amount of feed that must be given per day to sustain a cow under a specified set of conditions. In the **SOG calculator**, the DMI required per day to sustain a lactating cow, and other animals in the herd, determines the acres of each feedstuff that must be grown, as well as certain key production inputs required to produce animal feed (land, synthetic nitrogen fertilizer and pesticides).

The higher the quality of feed in terms of its nutrient concentrations and digestibility, the lower the DMI needed per day, assuming rations are always optimally balanced to assure that cows getting the proper mix of nutrients on a daily basis. High quality feed in an unbalanced ration will increase the amount of dry matter needed per day to sustain a lactating cow.

Step 6.1 establishes the DMI needed per day based on daily milk production levels. **Step 6.2** records the DMI needed per day to support a dry cow, heifers older than one year, and heifers less than a year of age. These feed intake values are subsequently used to estimate the total feed consumed by a lactating cow and her supporting animals.

Right above **Step 6.1,** DAILY MILK PRODUCTION (DMP) from **Step 3** is repeated for reference purposes and is reported in UNADJUSTED MILK PRODUCTION (UMPD) pounds or kilograms per day, and on the basis of ENERGY CORRECTED MILK (ECMPD) per day.

STEP 6.1. DRY MATTER INTAKE OF LACTATING COWS

Step 6. Total Dry Matter Intake per Milking Cow			
	Scenario 1 Dairy Farm 1		
Daily Milk Production:		**Converted Values**	**Source No.**
- Unadjusted Milk Production	60.0 lbs/day	27.22 kgs/day	Step 2
- Energy Corrected Milk (ECM)	61.5 lbs/day	27.91 kgs/day	Step 2
Step 6.1 Dry Matter Intake of Lactating Cows			
Dry Matter Intake at Unadjusted Milk Production Level per Day:	Choose one:		
- User Reported based on a dairy cow nutrition program or other source	○ lbs/day	0.00 kgs/day	
- Default	◉ 45.0 lbs/day	20.41 kgs/day	1
Dry Matter Intake Required per Lb/Kg of Milk:			
- Unadjusted Milk Production	0.75 lbs/day	0.34 kgs/day	2
- Energy Corrected Milk (ECM)	0.73 lbs/day	0.33 kgs/day	2

DRY MATTER INTAKE AT UNADJUSTED MILK PRODUCTION LEVEL PER DAY (DMIMP) is set in **SOG Version 1.1** at the default level of 45 pounds. This is a common level projected for high-production dairy farms feeding a well-balanced, high-quality total mixed ration (TMR). On a particular farm, this number will be driven lower or higher by many factors. In general, inadequate DMI per day will result in falling milk production and/or body condition. Adequate DMI per day, given the feedstuffs in the ration, will sustain milk production and animal body condition.

Dairy farmers and management specialists use a variety of lactating cow nutrition models to calculate daily DMI requirements. Several are based on the model developed and periodically updated by the National Research Council in its reports entitled *Nutrient Requirements of Dairy Cattle*. Several Universities have produced similar models that are often customized to more accurately reflect conditions on the dairy farms in the surrounding region. The Cornell – Penn-Minor Dairy (CPM-Dairy) nutrition model was developed by Cornell and Pennsylvania State University scientists and is one of the most widely used by veterinarians, dairy nutrition consultants, and the feed industry (Chalupa et al., 2004).

Private dairy nutrition consultants have further refined various models, again often to improve accuracy and relevance on farms with a defined, specific set of production characteristics.

Users are encouraged to rely on one of the proven dairy cow nutrition models to project DMI per day needed to sustain their cows based on the breed of cows, their condition, milk production goals, and feed rations on a given farm or group of farms covered in an application of the calculator.

DRY MATTER INTAKE REQUIRED PER POUND/KG OF MILK (DMIPPM) is the DRY MATTER INTAKE AT UNADJUSTED MILK PRODUCTION LEVEL PER DAY (DMIMP) divided by the DAILY UNADJUSTED MILK PRODUCTION LEVEl (UMPD). It is a key measure of the efficiency of a dairy farm.

POUNDS/KG OF UNADJUSTED MILK PER POUND/KG OF DRY MATTER INTAKE (PPMDMI) is the inverse of the previous variable, and is the pounds of milk produced per pound of DMI consumed per day.This variable is another important measure of feed efficiency.

STEP 6.2. DRY MATTER INTAKE OF OTHER ANIMALS IN HERD

Step 6.2 Dry Matter Intake of Other Animals in Herd					
Dry Matter Intake Required for Dry Cow per Day:	Choose one:				
- User Reported	○		lbs	0.00 kgs	
- Internally Calculated	●	22.93	lbs	10.40 kgs	4
Dry Matter Intake Required for Heifers > 1 per Day:	Choose one:				
- User Reported	○		lbs	0.00 kgs	
- Internally Calculated	●	18.39	lbs	8.34 kgs	4
Dry Matter Intake Required for Heifer < 1 per Day:	Choose one:				
- User Reported	○		lbs	0.00 kgs	
- Internally Calculated	●	7.44	lbs	3.37 kgs	4

The DMI required for other animals in the herd on a daily basis can be either USER REPORTED or DEFAULT values. Nennich et al. (2005) is the source of the DEFAULT values in **Step 6.2** for DMI/day for dry cows, heifers older than one year, and heifers under one year of age, as shown in the table below.

Default Values for DMI Required by Animal Type (Step 6)

Animal Type	Body Weight (kg)	DIM (kg)	Milk Production (kg)	DMI (kg)	Dietary CP (Crude Protein) (g/g of DM)	Dietary P (Phosphorpous) (g/g of DM)	Dietary K (Potassium) (g/g of DM)	Notes
Lactating Cow	630	172	31.4	21.7	0.175	0.0044	0.0129	Dietary P & K assume same as Mineral Cow
Lactating Cow w/ mineral info	617	165	31.5	21.9	0.0355	0.0044	0.0129	
Early Lactating Cow	591	38	66.5	18.2		0.0046	0.0157	
Dry Cow	755			10.4	0.133	0.0044	0.0129	Dietary P & K assume same as Mineral Cow
Heifer	437			8.34	0.112	0.0029	0.0147	
Calf	152.8			3.37	0.166	0.0037	0.0147	Dietary K assume same as Heifer

Notes: Where cell is blue, values were not given by Nennich and therefore assumed based on similar data as specified.
Source: Nennich, J. Dairy Science, Vol 88: 3721-3733.

Nennich et al. values are given for Holstein dairy cows at a specific body weight. The DMI required for dry cows, heifers >1 year of age and heifer < 1 year are adjusted proportionately based on the body weight designated in **Step 1.4.**

STEP 7. FEEDSTUFF YIELD ASSUMPTIONS AND DMI CONVERSIONS FOR FEED CROPS

A number of parameters are required to convert the estimated amounts of DRY MATTER INTAKE (DMI) from **Step 6** into estimated amounts of specific feeds consumed. Parameters like crop yields and storage losses are required to estimate the number of acres required to produce the feed consumed by an animal in a dairy herd. These key input parameters are incorporated in the calculator in **Step 7**.

This step divides all feeds into three broad categories of feedstuffs, FORAGES, GRAINS, and PROTEIN SUPPLEMENTS. **SOG Version 1.1** incorporates twelve specific sources of feed across these three major categories. In each category of feedstuffs, three additional rows are provided for a user to add additional sources of feed. Users must be aware, however, that if an additional source of feed is added, other corresponding data elements for that feed/crop must also be added elsewhere in the calculator in order for land and production input levels to be calculated (e.g., pounds of nitrogen fertilizer applied per acre in **Step 11**).

This step is broken into **Step 7a** and **Step 7b**. Space to record applicable data for two scenarios appears in each of these two **Step 7** tables. **Step 7a** reports these computations for **Scenario 1** and **Scenario 2** and **Step 7b** covers **Scenario 3** and **Scenario 4**.

STEP 7.1. FORAGE FEEDS

Step 7a. Feedstuff Yield Assumptions and DMI Conversions for Feed Crops

Crop	Scenario 1 Dairy Farm 1						
	Percent Dry Matter	Yield per Acre	Units	Pounds per Acre	Storage & Feeding Loss Adj. Factor	Prime Row Crop	Source/ Notes
Step 7a.1 Forage Feeds							
Dry alfalfa hay	90%	4.5	Tons	9,000	1.1	50%	3
Hay silage or baleage	30%	8.0	Tons	16,000	1.15	20%	4
Corn silage	33%	18.7	Tons	37,400	1.17	100%	3
Other dry hay	90%	3.0	Tons	6,000	1.1	20%	3
Pasture	30%	3.0	Tons	6,000	1	10%	5
Greenchop	30%	5.0	Tons	10,000	1.1	50%	6
[add forage crop here]							
[add forage crop here]							
[add forage crop here]							

The first column under each scenario records the PERCENT DRY MATTER of each specific feed in the typical form used in dairy rations. This percentage is used to convert the pounds of dry matter of a given crop/feed in the ration to pounds of the crop when harvested and placed into storage. The higher this percentage, the drier the feed source. Most types of dry hay are about 90% dry matter, while corn silage is only 33% dry matter. In most applications these values should be the same in all scenarios studied. The National Research Council publication *Nutrient Requirements of Dairy Cattle* (NRC, 2007) is generally regarded as the definitive source of data on the percent of dry matter in major dairy cow feedstuffs and is the source of default values in **SOG Version 1.1.**

The second column records the average YIELD PER ACRE in tons in the case of forage feeds, and the next column converts tons to POUNDS PER ACRE. Yields can be set at national, state, or regional averages. Alternatively, yields specific to a farm, or set of fields planted using the same crop genetics and agronomic systems, can be incorporated in **Step 7.**

The STORAGE AND FEEDING LOSS ADJUSTMENT FACTOR is specific for each feedstuff and is needed to take into account unavoidable harvest and storage losses when calculating the total amount of feed that must be produced and harvested to assure that a given amount of feed will be available for the dairy herd. This factor ranges from 10% in the case of feeds that store well and can be fed with minimal losses, to as high as 45% for certain feeds that are subject to considerable harvest loss and shrinkage in storage, or considerable waste when fed.

The column PRIME ROW CROP provides users an opportunity to estimate the percentage of a given feedstuff that is typically grown on prime, Class I row crop land, based on the classification system developed and applied to the nation's agricultural land base by the USDA's Natural Resources Conservation Service. The rest of the land needed to produce a given feedstuff (100- % Prime Land) is assumed to fall within NRCS Classes II through V, and reflects land subject to one or more production limitations such as high rates of soil erosion, stones, chemical imbalances (i.e., too much salt), etc.

In most regions, a high percentage of corn and corn silage is grown on prime farmland, whereas a relatively small portion of prime land would be devoted to pasture. Clearly, there will be exceptions to any estimate included in this column, e.g. a pasture-based dairy in a valley with predominantly Class I, prime farmland. But across large areas and significant numbers of dairy farms, reasonably accurate estimates can be made of the percent of the acres of a given crop grown on prime cropland, versus not prime cropland.

STEP 7.2. GRAINS

Step 7a.2 Grains

Corn	88%	153.9	Bushels	8,618	1.08	100%	3
Barley	88%	63.6	Bushels	3,053	1.08	67%	3
Oats	89%	63.5	Bushels	2,032	1.08	67%	3
Wheat	88%	47.2	Bushels	2,832	1.45	67%	3
[add grain crop here]							
[add grain crop here]							
[add grain crop here]							

The same columns appear in the section covering grain-based feeds, although in the case of grains, yields are typically expressed as bushels per acre. Bushels of grain feeds are converted to pounds using the standard conversion factors in the box below.

Crop Bushel Conversions	
Grains	Bushel
Corn	56
Barley	48
Oats	32
Wheat	60
Soybeans	60
Other protein	60
University of Kentucky, Grain Crops Extension	

STEP 7.3. PROTEIN SUPPLEMENTS

Step 7a.3 Protein Supplements							
Soybeans	90%	39.6	Bushels	2,376	1.1	100%	3
Other protein sources	90%	39.6	Bushels	2,376	1.1	100%	7
[add protein source here]							
[add protein source here]							
[add protein source here]							

As the case with grain-based feeds, **Step 7.3** converts yields stated as bushels of protein supplement feeds, such as soybeans, to pounds of protein feed per acre.

STEP 8. WORKSHEET FOR CALCULATION OF THE AVERAGE ANNUAL SHARE OF DRY MATTER INTAKE BY FEED BASED ON MONTHLY RATION FORMULATION

Dairy rations vary considerably from month to month, especially on dairy farms heavily reliant on pasture and forage-based feeds as a source of DMI. **Step 8a** and **Step 8b** provide farmers and calculator users a place to record data on the distribution of the DMI for the lactating cow rations by month across the 12 major feedstuffs included in the calculator and any additional feedstuff that the user may have added in **Step 7a.** The data on percent of DMI accounted for by each of twelve common dairy cow feeds is then averaged over the twelve months of the year, and the result is reported in the 12-MONTH AVERAGE DMI column just to the right of DEC in each of the four scenarios. These values are transferred to the next column labeled 12-MONTH AVERAGE DMI or ENTER USER REPORTED DMI, which will be automatically inserted in the corresponding lines for % DMI of each crop for the lactating cow in **Step 9a**. Users lacking such information can skip filling in the monthly percentages, and instead directly enter the average monthly distribution of DMI across the 12 major feedstuffs in this same column.

Important Note: This worksheet is designed to calculate Daily DMI for the lactating cow only. Daily DMI rations for other dairy animals are addressed in Step 9a and Step 9b.

Step 8 tables also reports the percent of total daily DMI accounted for by all forage feds, all grains, and all protein supplements. These three percentages must, in all cases, add up to 100%, as indicated in the last row TOTAL ALL FEEDS (MUST EQUAL 100%).

Step 8a reports these computations for **Scenario 1** and **Scenario 2** and **Step 8b** covers **Scenario 3** and **Scenario 4**.

STEP 8.1. FORAGE FEEDS

Step 8a. Worksheet for Calculation of Average Annual Share of Dry Matter Intake by Feed based on Monthly Ration Formulation

	Scenario 1 Dairy Farm 1													
	Percent of DMI for One Lactating Cow													
	Month of the Year												12-month Average DMI	12-month Average DMI or Enter User Reported DMI
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec		
Step 8a.1 Forage Feeds														
Dry alfallfa hay													0.0%	30.0%
Hay silage or baleage													0.0%	0.0%
Corn silage													0.0%	30.0%
Other dry hay													0.0%	5.0%
Pasture													0.0%	5.0%
Greenchop													0.0%	2.0%
													0.0%	0.0%
													0.0%	0.0%
													0.0%	0.0%
Total Forages	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	72%

STEP 8.2. GRAINS

	Month of the Year												12-month Average DMI	12-month Average DMI or Enter User Reported DMI
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec		
Step 8a.2 Grain														
Corn													0.0%	16.0%
Barley													0.0%	0.0%
Oats													0.0%	0.0%
Wheat													0.0%	0.0%
													0.0%	0.0%
													0.0%	0.0%
													0.0%	0.0%
Total Grain	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**16%**

STEP 8.3. PROTEIN SUPPLEMENTS

	Month of the Year												12-month Average DMI	12-month Average DMI or Enter User Reported DMI
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec		
Step 8a.3 Protein Supplements														
Soybeans													0.0%	12.0%
Other protein sources													0.0%	0.0%
													0.0%	0.0%
													0.0%	0.0%
													0.0%	0.0%
Total Protein	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**12%**
Total All Feeds (must equal 100%)	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**100%**

STEP 9. FEED COMPOSITION AS A PERCENT OF REQUIRED DRY MATTER INTAKE

This step breaks the broad categories of FORAGE FEEDS, GRAINS, and PROTEIN SUPPLEMENTS into specific crops and feed sources in the same manner as Steps 7 & 8. Note that the set of columns under each scenario report shares of DMI and daily feed intakes for:

- One Lactating Cow,
- One Dry Cow, and
- Heifers > 1 year old,and
- Heifers < 1 year old.

The PERCENT OF ANIMAL PER ONE LACTATING COW (PAOLC) is brought forward at the top of **Step 9** from **Step 1**, for each animal type. These percentages are used in **Step 9** to calculate the quantities of feed consumed by the dry cows and heifers needed to sustain the herd of lactating cows. For example, in a given application of **SOG**, a lactating cow might consume 27 pounds of forage feeds a day in a scenario, while dry cow forage consumption would be just 2.92 pounds. This is not because dry cows eat much less forage than lactating cows, but rather reflects the fact that just 13.3% of a dry cow is required to sustain one lactating cow under the other parameters in this hypothetical application. The amount of forage consumed by a dry cow in a day is computed by **SOG** at about 22 pounds (2.92 x [1/.133]).

Step 9a reports these computations for **Scenario 1** and **Scenario 2** and **Step 9b** covers **Scenario 3** and **Scenario 4**.

STEP 9.1. FORAGE FEEDS

Step 9a. Feed Composition as a Percent of Required Dry Matter Intake

	Scenario 1 Dairy Farm 1								
Animal Type	One Lactating Cow		Dry Cow		Heifers > 1		Heifers < 1		
Percent of Animal per One Lactating Cow (Step 1)	100%		16.2%		43.8%		44.6%		
	Daily Rations % DMI	DMI	Daily Rations % DMI	DMI	Daily Rations % DMI	DMI	Daily Rations % DMI	DMI	Total Daily DMI per Crop
Step 9a.1 Forage Feeds									
Dry alfallfa hay	30%	13.50 lbs.	50%	1.86 lbs.	50%	4.02 lbs.	50%	1.66 lbs.	21.04
Hay silage or baleage	0%	- lbs.		- lbs.		- lbs.		- lbs.	-
Corn silage	30%	13.50 lbs.		- lbs.		- lbs.		- lbs.	13.50
Other dry hay	5%	2.25 lbs.	15%	0.56 lbs.	15%	1.21 lbs.	15%	0.50 lbs.	4.51
Pasture	5%	2.25 lbs.	25%	0.93 lbs.	25%	2.01 lbs.	25%	0.83 lbs.	6.02
Greenchop	2%	0.90 lbs.	10%	0.37 lbs.	10%	0.80 lbs.	10%	0.33 lbs.	2.41
	0%	- lbs.		- lbs.		- lbs.		- lbs.	-
	0%	- lbs.		- lbs.		- lbs.		- lbs.	-
	0%	- lbs.		- lbs.		- lbs.		- lbs.	-
Total Forages	72%	32.40 lbs.	100%	3.72 lbs.	100%	8.05 lbs.	100%	3.31 lbs.	47.48

Step 9a addresses forage feed intakes across all classes of dairy animals. All percentages in daily rations for one lactating cow are drawn from **Step 8**. The percentages for the other animals can be entered here by overriding the values in the respective cells. The column to the right of the % DMI is

the total DMI (DMI) consumed of each feedstuff on a daily basis measured in pounds.
It is a calculated using the formula:

$$\text{Daily DMI (feedstuff}_x\text{)} = \text{\% DMI (feedstuff}_x\text{)} \times \text{TOTAL DMI / day} \times \text{PAOLC}$$

Where:
DMI per day
PAOLC is PERCENT OF ANIMAL PER ONE LACTATING COW

The fifth and final column in each scenario reports the TOTAL DAILY DMI ($TDDMI_{CROP}$) per crop (or feedstuff), and is the sum of pounds of DMI per feedstuff added across the four animal types.

The same process is duplicated for **Steps 9.2** for GRAIN crops and **9.3** for PROTEIN SUPPLEMENTS. At the bottom of **Step 9,** the SUM OF PERCENTS BY TYPE OF FEED (Value must equal 100%) adds together the percent of DMI satisfied by FORAGE FEEDS, GRAINS, and PROTEIN SUPPLEMENTS. If the sum of the % DMI by type of feed does not total 100%, a red error message appears at the bottom of the column.

STEP 9.2. GRAINS

	Daily Rations			Daily Rations			Daily Rations			Daily Rations			Total Daily
	% DMI	DMI		% DMI	DMI		% DMI	DMI		% DMI	DMI		DMI per Crop
Step 9a.2 Grain													
Corn	16%	7.20	lbs.		-	lbs.		-	lbs.		-	lbs.	7.20
Barley	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
Oats	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
Wheat	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
Total Grain	**16%**	**7.20**	**lbs.**	**0%**	**-**	**lbs.**	**0%**	**-**	**lbs.**	**0%**	**-**	**lbs.**	**7.20**

STEP 9.3. PROTEIN SUPPLEMENTS

	Daily Rations			Daily Rations			Daily Rations			Daily Rations			Total Daily
	% DMI	DMI		% DMI	DMI		% DMI	DMI		% DMI	DMI		DMI per Crop
Step 9a.3 Protein Supplements													
Soybeans	12%	5.40	lbs.		-	lbs.		-	lbs.		-	lbs.	5.40
Other protein sources	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
	0%	-	lbs.		-	lbs.		-	lbs.		-	lbs.	-
Total Protein	**12%**	**5.40**	**lbs.**	**0%**	**-**	**lbs.**	**0%**	**-**	**lbs.**	**0%**	**-**	**lbs.**	**5.40**
Sum of Percents by Type of Feed (Value should equal 100%)	**100%**			**100%**			**100%**			**100%**			

STEP 10. CROP ACRES REQUIRED TO PRODUCE THE FEEDSTUFFS FOR DAIRY ANIMALS

Step 10 calculates the amount of total land, and prime cropland, required to produce the feed needed to sustain a cow over a lactation of known length. It takes TOTAL DAILY DMI (TDDMI) per crops from **Step 9** for FORAGE FEEDS, GRAIN, and PROTEIN SUPPLEMENTS and converts the values to FEED REQUIRED PER DAY, ACRES REQUIRED TO PRODUCE FEED PER DAY, ACRES OF PRIME LAND REQUIRED PER DAY, ACRES REQUIRED PER LACTATION, and HECTARES REQUIRED PER LACTATION.

Step 10a reports these computations for **Scenario 1** and **Scenario 2** and **Step 10b** covers **Scenario 3** and **Scenario 4**.

STEP 10.1. FORAGE FEEDS

Step 10a. Crop Acres Required to Produce the Feedstuffs for Dairy Animals

	Scenario 1 Dairy Farm 1						
	DMI per Day for All Animal Types (pounds)	DMI to Pounds of Raw Feed Conversion	Feed Required per Day (pounds)	Acres Required to Produce Feed per Day	Acres of Prime Row Crop Required per Day	Acres Required per Lactation (357 days)	Hectacres Required per Lactation (357 days)
Step 10a.1 Forage Feeds							
Dry alfallfa hay	21.04	23.38	25.71	0.0029	0.0014	1.02	0.41
Hay silage or baleage	-	-	-	-	-	-	-
Corn silage	13.50	40.91	47.86	0.0013	0.0013	0.46	0.18
Other dry hay	4.51	5.01	5.51	0.0009	0.0002	0.33	0.13
Pasture	6.02	20.06	20.06	0.0033	0.0003	1.19	0.48
Greenchop	2.41	8.03	8.83	0.0009	0.0004	0.31	0.13
	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
Total Forages	**47.48**	**97.39**	**107.98**	**0.0093**	**0.0037**	**3.31**	**1.34**

Totals for each of the three major types of feed, appear at the bottom of each block.

DMI PER DAY FOR ALL ANIMAL TYPES (POUNDS) is directly from TOTAL DAILY DMI (TDDMI) per crop in **Step 9** and reflects the feed needed to support one lactating cow and her supporting animals over a single lactation.

DMI TO POUNDS OF RAW FEED CONVERSION converts the pounds of TDDMI needed per day to pounds of feedstuffs as harvested, taking into account typical moisture levels at harvest.

FEED REQUIRED PER DAY (POUNDS) is the amount of feed that must be harvested, taking into account harvest, storage and handling losses, to meet an animal's needs for DMI for one day. The percent values for these losses in **Step 7** are used in this calculation.

ACRES REQUIRED TO PRODUCE FEED PER DAY converts FEED REQUIRED PER DAY to the acres needed to grow that amount of crop, based on the crop yields specified in **Step 7.**

ACRES OF PRIME ROW CROP REQUIRED PER DAY is estimated by multiplying the ACRES REQUIRED TO PRODUCE FEED PER DAY by the percent of land producing a given feedstuff that is prime farmland, as recorded in **Step 7.**

ACRES REQUIRED PER LACTATION multiplies the acres required to produce a feedstuff per day by the number of days in a lactation, as recorded in **Step 3**. HECTARES REQUIRED PER LACTATION converts acres to hectares.

STEP 10.2. GRAINS

	DMI per Day for All Animal Types (pounds)	DMI to Pounds of Raw Feed Conversion	Feed Required per Day (pounds)	Acres Required to Produce Feed per Day	Acres of Prime Row Crop Required per Day	Acres Required per Lactation (357 days)	Hectacres Required per Lactation (357 days)
Step 10a.2 Grain							
Corn	7.20	8.18	8.84	0.0010	0.0010	0.37	0.15
Barley	-	-	-	-	-	-	-
Oats	-	-	-	-	-	-	-
Wheat	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
Total Grain	**7.20**	**8.18**	**8.84**	**0.0010**	**0.0010**	**0.37**	**0.15**

STEP 10.3. PROTEIN SUPPLEMENTS

	DMI per Day for All Animal Types (pounds)	DMI to Pounds of Raw Feed Conversion	Feed Required per Day (pounds)	Acres Required to Produce Feed per Day	Acres of Prime Row Crop Required per Day	Acres Required per Lactation (357 days)	Hectacres Required per Lactation (357 days)
Step 10a.3 Protein Supplements							
Soybeans	5.40	6.00	6.60	0.0028	0.0028	0.99	0.40
Other protein sources	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
Total Protein Supplements	**5.40**	**6.00**	**6.60**	**0.0028**	**0.0028**	**0.99**	**0.40**
Total Kgs/Day:	**27.25** kgs/day		**55.98** kgs/day				
Total Pounds/Day:	**60.08** lbs/day		**123.42** lbs/day				
Total Acres/Hectares Required:				**0.0131**	**0.0075**	**4.67** acres	**1.89** HA

STEP 11. ESTIMATES OF SYNTHETIC NITROGEN FERTILIZER AND PESTICIDES REQUIRED TO PRODUCE FEED FOR DAIRY ANIMALS

The impact of dairy farm management systems is driven in part by the inputs used to produce animal feed. This step uses national average input use per acre on conventional crops (in pounds) for synthetic nitrogen (NH4+, NH3+), herbicides, and insecticides. Synthetic nitrogen fertilizer, and in particular anhydrous ammonia (NH3+), is a significant source of nitrous oxide emissions (N2O), a potent greenhouse gas (Venterea et al., 2007).

This step calculates the quantities of these inputs required to produce crops on conventional farms. The energy and GHGs embedded in these inputs will be estimated in a future module. For some crops and years, the pounds applied of each of these inputs are reported in USDA's *Agricultural Chemical Usage Reports* (National Agriculture Statistics Service (NASS)). Certain major crops, such as corn grain, corn silage, wheat, and soybeans are surveyed by NASS almost every year, until recently. Barley was last surveyed in 2003, corn and oats in 2005, and soybeans in 2007. The most recent data available has been used in this calculator. Input use on the other forage feeds are estimated based on a variety of data sources and expert opinion.

Step 11a covers Scenario 1 and Scenario 2, and **Step 11b** covers Scenario 3 and Scenario 4. The next worksheet – **Step 11. Detail** , breaks out these data by type of animal: lactating cows, dry cows, and heifers > and < than one year.

STEP 11.1. FORAGE FEEDS

Step 11a. Estimates of Synthetic Nitrogen Fertilizer and Pesticides Required to Produce Feed for Dairy Animals

	National Average Inputs Applied per Acre on Conventional Crops (pounds)				Scenario 1 Dairy Farm 1			
	Synthetic Nitrogen per Acre	Herbicides per Acre	Insecticides per Acre	Source	Acres Required per Lactation	Synthetic Nitrogen (pounds N) per Lactation	Herbicides (pounds a.i.) per Lactation	Insecticides (pounds a.i.) per Lactation
Step 11a.1 Forage Feeds								
Dry hay	0	0.3	0.2	Interpolated	1.02	0.00	0.31	0.20
Hay silage or baleage	79	0.3	0.2	Interpolated	-	-	-	-
Corn silage	132	2.1	0.2	USDA, 2005	0.46	60.23	0.96	0.09
Other Dry Hay	79	0.3	0.2	Interpolated	0.33	25.95	0.10	0.07
Pasture	40	-	-	Interpolated	1.19	47.21	-	-
Greenchop	40	0.3	0.2	Interpolated	0.31	12.46	0.09	0.06
					-	-	-	-
					-	-	-	-
					-	-	-	-
Total Forages					3.31	145.85	1.46	0.42

ACRES REQUIRED PER LACTATION is derived from **Step 10**.

SYNTHETIC NITROGEN (POUNDS N) PER LACTATION is the acres of each crop required multiplied by the average pounds of nitrogen applied on that crop.

HERBICIDES (POUNDS A.I.) PER LACTATION is the acres of a given crop required per lactation multiplied by the average pounds of herbicides applied on that crop. Data on average pounds of pesticides applied per crop acre are derived directly from NASS surveys or is extrapolated from existing surveys or other sources.

INSECTICIDES (POUNDS A.I.) PER LACTATION is calculated in the same way as herbicides, and from the same data sources.

STEP 11.2. GRAIN

	Synthetic Nitrogen per Acre	Herbicides per Acre	Insecticides per Acre	Source	Acres Required per Lactation	Synthetic Nitrogen (pounds N) per Lactation	Herbicides (pounds a.i.) per Lactation	Insecticides (pounds a.i.) per Lactation
Step 11a.2 Grain								
Corn	132	2.1	0.2	Interpolated	0.37	48.25	0.77	0.07
Barley	57	0.7	0.1	USDA, 2003	-	-	-	-
Oats	25	1.0	0.03	USDA, 2005	-	-	-	-
Wheat	58	0.4	0.01	USDA, 2006	-	-	-	-
					-	-	-	-
					-	-	-	-
					-	-	-	-
Total Grain					**0.37**	**48.25**	**0.77**	**0.07**

STEP 11.3. PROTEIN SUPPLEMENTS

	Synthetic Nitrogen per Acre	Herbicides per Acre	Insecticides per Acre	Source	Acres Required per Lactation	Synthetic Nitrogen (pounds N) per Lactation	Herbicides (pounds a.i.) per Lactation	Insecticides (pounds a.i.) per Lactation
Step 11a.3 Protein Supplements								
Soybeans	3	1.0	0.03	USDA, 2006	0.99	2.97	0.99	0.03
Other protein sources	50	1.5	0.10	Interpolated	-	-	-	-
					-	-	-	-
					-	-	-	-
					-	-	-	-
Total Protein					**0.99**	**2.97**	**0.99**	**0.03**
Total Crop Inputs (kgs/Lactation):						**89.39** kgs	**1.46** kgs	**0.24** kgs
Total Crop Inputs (lbs/Lactation):						**197.08** lbs	**3.21** lbs	**0.53** lbs

STEP 11. - DETAIL. SYNTHETIC NITROGEN FERTILIZER AND PESTICIDES REQUIRED TO PRODUCE FEED PER COW TYPE PER DAY

This detailed worksheet elaborates on **Step 11,** showing in detail the NUMBER OF ACRES REQUIRED TO PRODUCE FEED, and the amount of SYNTHETIC NITROGEN, HERBICIDES, and INSECTICIDES used on FEED CROPS PER ANIMAL TYPE PER DAY. The TOTAL DAILY AMOUNTS OF INPUTS used for all crops for all dairy animals is reported in the bottom line, and also appears in the Results II table.

STEP 11.1. - DETAIL FORAGE FEEDS

Step 11a.Detail. Synthetic Nitrogen Fertilizer and Pesticides Required to Produce Feed per Cow Type per Day

	Scenario 1 Dairy Farm 1			
	All Animals			
	Acres Required per Day	Synthetic Nitrogen per Day	Herbicides per Day	Insecticides per Day
Step 11a.1 Forage Feeds:				
Dry hay	0.002857	0.000000	0.000857	0.000571
Hay silage or baleage	-	-	-	-
Corn silage	0.001280	0.168930	0.002688	0.000256
Other Dry Hay	0.000919	0.072788	0.000276	0.000184
Pasture	0.003344	0.132426	-	-
Greenchop	0.000883	0.034961	0.000265	0.000177
	-	-	-	-
	-	-	-	-
	-	-	-	-
Total Forages	**0.009283**	**0.409105**	**0.004085**	**0.001188**

STEP 11.2. - DETAIL GRAIN

	Acres Required per Day	Synthetic Nitrogen per Day	Herbicides per Day	Insecticides per Day
Step 11a.2 Grain:				
Corn	0.001025	0.135338	0.002153	0.000205
Barley	-	-	-	-
Oats	-	-	-	-
Wheat	-	-	-	-
	-	-	-	-
	-	-	-	-
	-	-	-	-
Total Grain	**0.001025**	**0.135338**	**0.002153**	**0.000205**

STEP 11.3. - DETAIL PROTEIN SUPPLEMENTS

	Acres Required per Day	Synthetic Nitrogen per Day	Herbicides per Day	Insecticides per Day
Step 11a.3 Protein Supplements:				
Soybeans	0.002778	0.008333	0.002778	0.000083
Other protein sources	-	-	-	-
	-	-	-	-
	-	-	-	-
	-	-	-	-
Total Protein	**0.002778**	**0.008333**	**0.002778**	**0.000083**
Totals for all Crops (lbs)	**0.01309**	**0.55278**	**0.00902**	**0.00148**

STEP 12. OTHER MEASURES OF DIETARY INTAKES BY TYPE OF DAIRY ANIMAL

The models used to estimate greenhouse gas emissions and other wastes generated by dairy farm operations utilize as input parameters a number of measures of the various nutrients in dairy rations. Three of the most commonly used metrics are DIETARY CRUDE PROTEIN, DIETARY PHOSPHORUS, and DIETARY POTASSIUM, each of which is estimated for the four classes of animals in **Step 12**.

The crude protein in a diet impacts the nitrogen concentration in animal urine and manure, and as a result, impacts potential and actual GHG emissions. It also helps determine milk protein content.

Phosphorus and potassium are critical plant and animal nutrients, which can also contribute to water quality degradation. Phosphorus is of particular significance due to its role in freshwater eutrophication and the creation and expansion of dead zones in coastal waters, such as the Gulf of Mexico.

All DEFAULT values in **Step 12** are derived from the work of Nennich et al. (2005) by adjusting his published values proportionately by the DMI required for each type of animal, as calculated in **Step 6**.

STEP 12.1. DIETARY INTAKES FOR LACTATING COWS

Step 12. Other Measures of Dietary Intakes by Type of Dairy Animal	Scenario 1 Dairy Farm 1	
Step 12.1 Dietary Intakes for Lactating Cow		
		Source No.
Dietary Crude Protien (CP):	Choose one:	
- User Reported	○ g/g of DM	
- Default	◉ 0.165 g/g of DM	1
Dietary Phosphorus (P):	Choose one:	
- User Reported	○ g/g of DM	
- Default	◉ 0.0041 g/g of DM	1
Dietary Potassium (K):	Choose one:	
- User Reported	○ g/g of DM	
- Default	◉ 0.0121 g/g of DM	1

DIETARY CRUDE PROTEIN, DIETARY PHOSPHORUS, and DIETARY POTASSIUM are reported in this step in grams per gram of dry matter. In **SOG Version 1.1**, the default values from Nennich et al. (2005) reflect averages across a large set of farms studied by Nennich and colleagues. One of several dairy cow nutrition models can be used to more accurately project dietary protein, phosphorous, and potassium intake levels based on specific rations. Most of these models, including the CPM-Dairy model (Chalupa, et al., 2004), report DMI required per day at a given milk production level, as well as crude protein, phosphorous, and potassium intakes based on the rations entered into the model. These outputs can be entered as USER REPORTED values in **Step 12.**

STEP 12.2. DIETARY INTAKES FOR ONE DRY COW

Step 12.2 Dietary Intakes for One Dry Cow		
Dietary Crude Protien (CP):	Choose one:	
- User Reported	○ [ ] g/g of DM	
- Default	● 0.133 g/g of DM	1
Dietary Phosphorus (P):	Choose one:	
- User Reported	○ [ ] g/g of DM	
- Default	● 0.0044 g/g of DM	2
Dietary Potassium (K):	Choose one:	
- User Reported	○ [ ] g/g of DM	
- Default	● 0.0129 g/g of DM	1

STEP 12.3. DIETARY INTAKES FOR ONE HEIFER > 1

Step 12.3 Dietary Intakes for One Heifer > 1		
Dietary Crude Protien (CP):	Choose one:	
- User Reported	○ [ ] g/g of DM	
- Default	● 0.112 g/g of DM	1
Dietary Phosphorus (P):	Choose one:	
- User Reported	○ [ ] g/g of DM	
- Default	● 0.0029 g/g of DM	1
Dietary Potassium (K):	Choose one:	
- User Reported	○ [ ] g/g of DM	
- Default	● 0.0147 g/g of DM	1

STEP 12.4. DIETARY INTAKES FOR HEIFER < 1

Step 12.4 Dietary Intakes for Heifer < 1		
Dietary Crude Protien (CP):	Choose one:	
- User Reported	○ [ ] g/g of DM	
- Default	● 0.166 g/g of DM	1
Dietary Phosphorus (P):	Choose one:	
- User Reported	○ [ ] g/g of DM	
- Default	● 0.0037 g/g of DM	1
Dietary Potassium (K):	Choose one:	
- User Reported	○ [ ] g/g of DM	
- Default	● 0.0147 g/g of DM	3

STEP 13. DAILY MANURE AND NUTRIENT EXCRETION PREDICTIONS FROM DAIRY CATTLE

Several factors help determine the volume of urine and manure produced by a cow on a given day, and another set of factors determine the nutrient concentrations in the urine and manure. Manure and urine volume are driven primarily by animal breed and size, levels of milk production, and the specific feeds included in the ration, coupled with the balance of nutrients within a ration.

As the case in several other steps, **Step 13a** covers Scenario 1 and Scenario 2 and **Step 13b** covers Scenario 3 and Scenario 4. Each worksheet projects manure and nutrient excretions by type of animal: lactating cows, dry cows, heifers over one year, and heifers less than one year of age. At the bottom of **Step 13a** and **13b**, total manure and nutrient excretions are calculated.

STEP 13.1. ONE LACTATING COW CONTRIBUTION

Step 13a. Daily Manure and Nutrient Excretion Predictions from Dairy Cattle

	Scenario 1 Dairy Farm 1					
Step 13a.1 One Lactating Cow Contribution						
	Converted Values					Source No.
Manure Excretion (ME):	Choose one:					
- User Reported	○	0.0	lbs/day		kgs/day	
- Internally Calculated	●	139.1	lbs/day	63.08	kgs/day	1
Dry Matter Excretion (DME):	Choose one:					
- User Reported	○	0.00	lbs/day		kgs/day	
- Internally Calculated	●	17.78	lbs/day	8.07	kgs/day	1
Nitrogen Excretion (NE):	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on Milk Production	○	0.340	lbs/day	0.15	kgs/day	2
- Calculated based on Dietary CP	●	0.904	lbs/day	0.41	kgs/day	1
Phosphorus Excretion (PE):	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on Milk Producton	○	0.179	lbs/day	0.08	kgs/day	2
- Calculated based on Dietary P	●	0.151	lbs/day	0.07	kgs/day	1
Potassium Excretion (KE):	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Internally Calculated	●	0.388	lbs/day	0.18	kgs/day	1

MANURE EXCRETION (ME) and DRY MATTER EXCRETION (DME) are functions of forage and feedstuff quality and the water content of manure, respectively. The user can choose a DEFAULT value for these parameters or may enter USER REPORTED (farm-specific data), which may markedly influence all subsequent calculations. The structure and function of the equations described below are basically the same. **Steps 13.1** to **13.4** cover the four basic categories of animals. **Step 13.5** is the sum of the manure produced and nutrient excretions for one lactating cow for a year and the supporting animals needed to sustain her.

MANURE EXCRETION (ME) is calculated and expressed in both English and metric units.

The formula used to internally calculate MANURE EXCRETION is derived from the work of Nennich (2005):

$$ME = [DMI\ (kg) \times 2.63] + 9.4$$

Where:
DMI is the DRY MATTER INTAKE

DRY MATTER EXCRETION (DME) is also internally calculated using Nennich's formula:

$$DME = [DMI\ (kg) \times 0.356] + 0.8$$

Where:
DMI is the DRY MATTER INTAKE

For NITROGEN EXCRETION (NE), PHOSPHORUS EXCRETION (PE), and POTASSIUM EXCRETION (KE), users are encouraged to enter values based on testing of manure from a specific herd or herds of interest. This type of test will greatly improve the accuracy of subsequent calculations and can be performed by a university affiliated agricultural testing laboratory for about $35 per sample. In general,manure tends to be 14%-34% C, 0.8%-1.45% N, 0.2%-0.4% P, and 1.3%-3.3% K (Lekasi et al. 2003). Otherwise, values will be INTERNALLY CALCULATED as described below.

NITROGEN EXCRETION (NE) can be determined in three ways. It can be USER REPORTED or INTERNALLY CALCULATED using two different methods. The first method is based on UNADJUSTED MILK PRODUCTION per day, using the equation:

$$NE = UMPD\ (kg/day) \times 5.15\ (g/day)/1000$$

Where:
UMPD is UNADJUSTED MILK PRODUCTION PER DAY

Alternatively, NE can be INTERNALLY CALCULATED using the equation recommended by Nennich et al. (2005) as follows:

$$NE = \left(\frac{(DMI \times DCP \times 84.1) + (BW \times 0.196)}{1000} \right)$$

Where:
DMI is the DRY MATTER INTAKE
DCP is the DIETARY CRUDE PROTEIN intake within the daily diet
BW is the BODY WEIGHT of the animal

PHOSPHORUS EXCRETION (PE) can also be determined in three ways. It can be USER REPORTED, and INTERNALLY CALCULATED using the standard formula based on UNADJUSTED MILK PRODUCTION:

$$PE = (\text{UMPD kg/day}) \times \left(\frac{2.98 \text{ g/day}}{1{,}000} \right)$$

Where:
UDMP is the UNADJUSTED DAILY MILK PRODUCTION

PE can also be INTERNALLY CALCULATED using Nennich's formula, which incorporates the DIETARY PHOSPHORUS intake. According to Nennich, "P intake is the best single independent variable for predicting PE".

$$PE = \left(\frac{(DMI \times DP \times 560.7) + 21.1}{1000} \right)$$

Where:
DMI is the DRY MATTER INTAKE
DP is the DIETARY PHOSPHORUS intake within the daily diet.

POTASSIUM EXCRETION (KE) is also calculated using Nennich's recommended formula (2005):

$$KE = \left(\frac{(DMI \times 7.21) + (DK \times 15{,}944) - 164.5}{1000} \right)$$

Where:
DMI is the DRY MATTER INTAKE
DK is the DIETARY POTASSIUM intake within the daily diet

STEP 13.2. ONE DRY COW CONTRIBUTION

The equations used to internally calculate the nutrient excretions for one dry cow are exactly the same as the lactating cow and are repeated as follows. (see next page)

Step 13a.2 One Dry Cow Contribution	Converted Values					Source No.
Manure Excretion (ME):	Choose one:					
- User Reported	○	0.0	lbs/day		kgs/day	
- Internally Calculated	●	81.0	lbs/day	36.75	kgs/day	1
Dry Matter Excretion (DME):	Choose one:					
- User Reported	○	0.00	lbs/day		kgs/day	
- Internally Calculated	●	9.93	lbs/day	4.50	kgs/day	1
Nitrogen Excretion (NE):	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Internally Calculated	●	0.583	lbs/day	0.26	kgs/day	1
Phosphorus Excretion (PE):	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Internally Calculated	●	0.103	lbs/day	0.05	kgs/day	1
Potassium Excretion (KE):	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Internally Calculated	●	0.256	lbs/day	0.12	kgs/day	1

MANURE EXCRETION (ME):

$$ME = (DMI\ (kg) \times 2.63) + 9.4$$

DRY MATTER EXCRETION (DME):

$$DME = [DMI\ (kg) \times 0.356] + 0.8$$

NITROGEN EXCRETION (NE):

$$NE = \left(\frac{(DMI \times DCP \times 84.1) + (BW \times 0.196)}{1000} \right)$$

PHOSPHORUS EXCRETION (PE):

$$PE = \left(\frac{(DMI \times DP \times 560.7) + 21.1}{1000} \right)$$

POTASSIUM EXCRETION (KE):

$$KE = \left(\frac{(DMI \times 7.21) + (DK \times 15{,}944) - 164.5}{1000} \right)$$

STEP 13.3. ONE HEIFER > 1 CONTRIBUTION

The equations used to INTERNALLY CALCULATE nutrient excretions for one heifer greater that one year of age vary slightly from the above equations

Step 13a.3 One Heifer > 1 Contribution						
	Converted Values					Source No.
Manure Excretion (ME):	Choose one:					
- User Reported	○	0.0	lbs/day		kgs/day	
- Internally Calculated	●	52.7	lbs/day	23.91	kgs/day	1
Dry Matter Excretion (DME):	Choose one:					
- User Reported	○	0.00	lbs/day		kgs/day	
- Internally Calculated	●	8.31	lbs/day	3.77	kgs/day	1
Nitrogen Excretion (NE):	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Internally Calculated	●	0.275	lbs/day	0.12	kgs/day	1
Phosphorus Excretion (PE):	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Internally Calculated	●	0.076	lbs/day	0.03	kgs/day	1
Potassium Excretion (KE):	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Internally Calculated	●	0.287	lbs/day	0.13	kgs/day	1

MANURE EXCRETION (ME) not only accounts for a higher contribution from DMI, but also for the heifer's body weight.

$$ME = [DMI\ (kg) \times 4.158] - (BW \times 0.0246)$$

Where:
DMI is the DRY MATTER INTAKE
BW is the BODY WEIGHT of the animal

DRY MATTER EXCRETION (DME):

$$DME = [DMI\ (kg) \times 0.356] + 0.8$$

Where:
DMI is the DRY MATTER INTAKE

NITROGEN EXCRETION (NE): for one heifer > 1, is not based on body weight as above, but uses a constant of 51.4, derived thru regression analysis and uses a slightly lower coefficient for DCP (78.4).

$$NE = \left(\frac{(DMI \times DCP \times 78.4) + 51.4}{1000} \right)$$

Where:
DMI is the DRY MATTER INTAKE
DCP is the DIETARY CRUDE PROTEIN intake within the daily diet

PHOSPHORUS EXCRETION (PE):

$$PE = \left(\frac{(DMI \times DP \times 560.7) + 21.1}{1000} \right)$$

Where:
DMI is the DRY MATTER INTAKE
DP is the DIETARY PHOSPHORUS intake within the daily diet

POTASSIUM EXCRETION (KE):

$$KE = \left(\frac{(DMI \times 7.21) + (DK \times 15{,}944) - 164.5}{1000} \right)$$

Where:
DMI is the DRY MATTER INTAKE
DK is the DIETARY POTASSIUM intake within the daily diet

STEP 13.4. ONE HEIFER < 1 (CALF) CONTRIBUTION

MANURE EXCRETIONS (ME) for one heifer calf, according to Nennich et al. (2005), is about half the ME from a heifer one year or older, even though the average calf body weight is about a third of a heifer older than one year.

Step 13a.4 One Heifer < 1 Contribution	**Converted Values**			**Source No.**
Manure Excretion (ME):	Choose one:			
- User Reported	○	0.0 lbs/day	kgs/day	
- Internally Calculated	●	25.7 lbs/day	11.64 kgs/day	1
Dry Matter Excretion (DME):	Choose one:			
- User Reported	○	0.00 lbs/day	kgs/day	
- Internally Calculated	●	2.92 lbs/day	1.33 kgs/day	1
Nitrogen Excretion (NE):	Choose one:			
- User Reported	○	0.000 lbs/day	kgs/day	
- Internally Calculated	●	0.139 lbs/day	0.06 kgs/day	1
Phosphorus Excretion (PE):	Choose one:			
- User Reported	○	0.000 lbs/day	kgs/day	
- Internally Calculated	●	0.017 lbs/day	0.01 kgs/day	1
Potassium Excretion (KE):	Choose one:			
- User Reported	○	0.000 lbs/day	kgs/day	
- Internally Calculated	●	0.208 lbs/day	0.09 kgs/day	1

ME for calves is calculated as:

$$ME = [DMI\ (kg) \times 3.45]$$

Where:
DMI is the DRY MATTER INTAKE

DRY MATTER EXCRETION (DME) varies in calculation, as well, from the other categories of animals.

$$DME = [DMI\ (kg) \times 0.39]$$

Where:
DMI is the DRY MATTER INTAKE

NITROGEN EXCRETION (NE) is directly related to DCP intake for calves. The coefficient for DCP intake is greater than for heifers > 1. Therefore, 112.6 is used instead of 78.4.

$$NE = \left(\frac{(DMI \times DCP \times 112.6)}{1000} \right)$$

Where:
DMI is the DRY MATTER INTAKE
DCP is the DIETARY CRUDE PROTEIN intake within the daily diet

PHOSPHORUS EXCRETION (PE): Nennich et al. (2005) found that there was a direct relationship between PE and DP in calves and therefore recommends the following equation.

$$PE = [DMI \times DP \times 622.0]$$

Where:
DMI is the DRY MATTER INTAKE
DP is the DIETARY PHOSPHORUS intake within the daily diet

POTASSIUM EXCRETION (KE):

$$KE = \left(\frac{(DMI \times 7.21) + (DK \times 15{,}944) - 164.5}{1000} \right)$$

Where:
DMI is the DRY MATTER INTAKE
DK is the DIETARY POTASSIUM intake within the daily diet

STEP 13.5. TOTAL IMPACT

Step 13a.5 Total Impact of Nutrient Excretions from One Lactating Cow and its Sustaining Herd					
Percent of Animal to One Lactating Cow (Step 1)	Lactating Cow Dry Cow Heifer > 1 Heifer < 1		100% 16% 44% 45%		
Manure Excretion (ME):	**186.7**	**lbs/day**	**84.7**	**kgs/day**	
Dry Matter Excretion (DME):	**24.3**	**lbs/day**	**11.0**	**kgs/day**	
Nitrogen Excretion (NE):	**1.18**	**lbs/day**	**0.54**	**kgs/day**	
Phosphorus Excretion (PE):	**0.21**	**lbs/day**	**0.09**	**kgs/day**	
Potassium Excretion (KE):	**0.65**	**lbs/day**	**0.29**	**kgs/day**	

This portion of **Step 13** is the sum of **Steps 13.1** to **13.4**. The value for each animal type is multiplied by the associated PERCENT OF ANIMAL THAT SUPPORTS ONE LACTATING COW (PAOLC, from **Step 1**), and then added together.

This is also an estimate of the amount of carbon (i.e. DME), NITROGEN (NE), PHOSPHORUS (PE), and POTASSIUM (KE) a given farm has available to supplement its fertilizer requirements or those of its neighbors, as well as a measure of how much each operation is loading into the surrounding rivers, streams, and groundwater.

STEP 14. FACTORS GOVERNING GREENHOUSE GAS EMISSIONS

Many factors impact greenhouse gas (GHG) emissions from dairy operations. Some increase or decrease waste stream flows, or alter the content of waste streams, while others impact the degree to which GHG-producing nutrients in waste streams are captured in the terrestrial ecosystem, flow into water, or escape to the atmosphere as GHGs. On-farm dairy operations contribute to GHGs, as do farming operations and inputs needed to grow dairy farm feedstuffs. Transportation, heating, processing, and refrigeration are other important factors that must be taken into account in a life-cycle assessment of dairy sector GHG emissions.

Step 14 provides users of **SOG** an opportunity to project the impact of major manure management system options on the methane portion of GHG emissions. The input parameter values and calculations in this step play a direct role in the estimation of methane emissions from manure and enteric fermentation in **Step 15**, and will also be important in the future when a module is added to **SOG** to project CO2 and nitrous oxide emissions

STEP 14.1. WASTE MANAGEMENT SYSTEM (WMS)

All values in **Step 14.1** and **Step 14.2** are drawn from the 2007 EPA report *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007* or the 2006 IPCC report *Guidelines for National Greenhouse Gas Inventories.*

The climate in a region has a major impact on the Methane Conversion Factor (MCF) applicable to a given manure management system because rates of Methane (CH4) emissions are closely tied to the amount of oxygen available and the temperature of the surrounding environment. Methane losses can increase by 400% for every 50°F, which in many cold and temperate regions is the difference between average summer high and average winter low temperatures.

For this reason, **SOG Version 1.1** provides users a chance to designate in each scenario the STATE and CLIMATE via two drop down boxes right above **Step 14.1**. The STATE affects the MCF applied for wet WMSs and the CLIMATE affects the MCF for the dry WMSs. In its most recent national inventory of GHG emissions, the EPA reports Methane Conversion Factors by type of manure management system (Chapter 3.10 "Methodology for Estimating CH_4 and N_2O Emissions from Manure Management," EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Tables A-174 and A-175). These tables are listed in the DEFAULTS worksheet in **SOG version 1.1**. These factors are embedded in multiple calculations in **Steps 14-15**.

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Step 14a covers **Scenario 1** and **Scenario 2**, while **Step 14b** covers **Scenario 3** and **Scenario 4**. For users wishing to project impacts of dairy management in a region, users should select the most representative STATE within the region in **Step 14** in terms of climate and manure management systems. In carrying out applications focusing on the national dairy industry, a state with a mix of manure management systems that also lacks extremes in climate should be selected (e.g., Missouri, Washington State, or Ohio).

Step 14a. Factors Governing Greenhouse Gas Emissions

	Scenario 1 Dairy Farm 1			
State/Type of Climate:	WA	Temperate		
Step 14a.1 Waste Management System (WMS)				
Wet Systems:	**Percent of Manure**	**MCF**	**Weighted MCF**	**Source No.**
Anaerobic Lagoon	70%	0.63	0.441	1
Liquid/Slurry		0.21	0	
Dry Systems:				
Pasture	5%	0.015	0.00075	1
Daily spread		0	0	
Solid Storage	10%	0.04	0.004	
Deep Pit		0	0	
Composting Intensive		0.01	0	
Dry Lot	15%	0.015	0.00225	
Total WMS:	**100%**		**0.448**	
WMS Methane Conversion Factor (MCF):	Choose one:			
- User Reported	○			
- Internally Calculated	◉ 0.448			above
CH4 Producing Potential of Waste (B_O):	0.24			2
Percent Diet Digestibility (%DD):	Choose one:			
- User Reported	○			
- Default	◉ 65%			3

Two liquid or wet manure management system options are currently provided in **Step 14** - ANAEROBIC LAGOON and LIQUID/SLURRY. The former is by far the most common system on most large-scale dairy farms across the nation. Six dry manure system management options are modeled:

- PASTURE
- DAILY SPREAD
- SOLID STORAGE
- DEEP PIT
- COMPOSTING INTENSIVE, and
- DRY LOT

In the column PERCENT OF MANURE in each scenario, users must specify the percentage of the total volume of manure generated in a year on a farm, or farms that were managed using each of these eight manure management options. The sum of percentages across the eight options must add to 100%. A warning message will appear when it does not.

The column just to the right labeled MCF reports the METHANE CONVERSION FACTOR (MCF) applicable to each manure management option in the chosen STATE and/or CLIMATE TYPE designated. The tables reporting methane convention factors by state and climate appear in the DEFAULTS worksheet, and are currently locked (i.e., password protected) to prevent inadvertent changes in values that could impair future **SOG** applications. Users interested in altering these default MCFs should contact Charles Benbrook (cbenbrook@organic-center.org). Alternatively, users can input their own methane conversion factor in the USER REPORTED line in the WMS METHANE CONVERSION FACTOR box.

The average methane conversion factor applicable to a farm or set of farms within a scenario can be calculated using a weighted average formula, whereby the PERCENT OF MANURE managed in each of the eight options is multiplied by the applicable MCF. This is done in the column WEIGHTED MCF.

The sum of WEIGHTED MCFs appears in the TOTAL WMS row and is automatically recorded in the next box – WMS METHANE CONVERSION FACTOR – as the INTERNALLLY CALCULATED value. Users can provide a USER REPORTED WMS MCF applicable to a specific manure management system, or select the INTERNALLY CALCULATED value, which is subsequently used in **Step 15** to calculate CH_4 emissions.

CH_4 PRODUCING POTENTIAL OF WASTE (B_O) is the value that represents the maximum amount of CH_4 (methane) that can be produced from waste as reported by Woodbury and Hashimoto (1993).

PERCENT DIET DIGESTIBILITY (%DD) represents the percent of gross energy intake digested by a dairy animal. The EPA developed a table estimating the %DD by region using a model (Donovan and Baldwin 1999) that represents physiological processes in ruminant animals such as, body weight, age, and feed characteristics. By selecting the state at the beginning of **Step 14**, the appropriate %DD is selected according to the region in which a state falls.

STEP 14.2. ENERGY

Lactating dairy cows utilize energy consumed in their diet for general body maintenance, activity (like walking to and from pastures), lactation, and pregnancy. **Step 14.2** calculates estimates of these various energy expenditures expressed in terms of millijoules per day (mj/day). In all cases, "User Reported" values can be added if available for the farm or farms that are the focus of a given scenario.

Step 14a.2 Energy		
Net Energy:		
for Maintenance NE(m)	49.69	4
for Activity NE(a)	-	4
for Lactation NE(l)	80.29	4
for Pregnancy NE(p)	4.97	4
Total Net Energy:	**134.95 mj/day**	
Ratio of Energy for Maintenance (REM):	0.514 kg	4
Digestible Energy (DE):	Choose one:	
- User Reported	○ mj/day	
- Internally Calculated (based on Unadjusted Milk Production)	● 262.63 mj/day	4
Gross Energy Intake (GE):	Choose one:	
- User Reported	○ mj/day	
- Internally Calculated	● 404.04 mj/day	4
Portion of GE converted to CH4 (Ym):	5.8%	5
Volatile Solids Produced (VSP):	Choose one:	
- User Reported	○ kg	
- Internally Calculated	● 7.44 kg	6

TOTAL NET ENERGY (TNE) distributes a lactating cow's daily energy intake across the four designated major uses of energy. The equations used in doing so are standard ones used by dairy scientists and have been chosen by the EPA for use in its inventory of GHG emissions.

The formula for NET ENERGY FOR MAINTENANCE NE(m) is:

$$NE(m) = 0.386 \text{ x } (BW_{\text{LACTATING COW}}(kg))^{0.75}$$

Where:
BW is the BODY WEIGHT of the lactating cow

The formula for NET ENERGY FOR ACTIVITY NE(a) is:

$$NE(a) = NE(m) \text{ x } Ca$$

Where:
Ne(m) is the NET ENERGY for MAINTENANCE
Ca is a coeffecient that represents the fraction of the herd in the region that grazes during the year. According to EPA, these coefficients are 0.0 for feedlot conditions and 0.17 for high quality confined pasture conditions. In **SOG Version 1.1**, it is assumed that conventional farms generally adhere to feedlot conditions, while organic farms graze on high quality confined pastures.

The formula for NET ENERGY FOR LACTATION NE(l) is:

NE(l) = UMPD (kg) x (1.47 + 0.4 x % MILKFAT)

Where:
UMPD is the DAILY UNADJUSTED MILK PRODUCTION PER DAY
% MILKFAT is the PERCENT MILK FAT

The formula for NET ENERGY FOR PREGNANCY NE(p) is:

NE(p) = 0.1 x NE(m)

Where:
NE(m) is NET ENERGY FOR MAINTENANCE

The formula for TOTAL NET ENERGY (TNE) is:

TNE = NE(m) + NE(a) + NE(l) + NE(p)

Important Note: As the percent of lactating cow DMI from pasture rises, the energy expenditures by cows required to walk to, from and within pastures will increase overall DMI and NET ENERGY needs. Ideally, when using a dairy cow nutrition model to calculate the DMI required to maintain a given level of milk production under a specified ration, the energy invested in reaching and grazing pastures should be taken into account to assure that the DMI provided to lactating cows is sufficient to sustain body condition and overall cow health. The greater the reliance on pasture, the more important this factor becomes.

RATIO OF ENERGY FOR MAINENANCE (REM) is a function of PERCENT DIET DIGESTIBILITY (%DD). This implicitly measures two components of energy flow:

- feed quality and
- the degree to which dairy cows must work to attain the requisite energy they need to produce

$$\text{REM} = \left(1.123 - \left(0.004092 \times \%\text{DD}\right) + \left(0.00001126 \times \%\text{DD}^2\right)\right) - \left(\frac{25.4}{\%\text{DD}}\right)$$

milk.
Where:
%DD is the PERCENT DIET DIGESTIBILITY

DIGESTIBLE ENERGY (DE) measures the portion of a dairy cow's daily energy intake it uses to exist and is TOTAL NET ENERGY/REM.

GROSS ENERGY INTAKE (GE) is DE divided by the %DD and is the amount of material a cow has the capacity to assimilate via rumen activity on a daily basis. DIGESTIBLE to GROSS ENERGY is a measure of feed-use efficiency and will vary substantially at different life-stages and with varying qualities of feed.

GE = TNE / REM / %DD

Where:
TNE is TOTAL NET ENERGY
REM is RATIO OF ENERGY FOR MAINTENANCE
%DD is the PERCENT DIET DIGESTIBILITY

PORTION OF GE CONVERTED TO CH_4 (Ym) is a conversion factor that represents the percent of GROSS ENERGY INTAKE that is converted to methane gas. PORTION OF GE CONVERTED TO CH_4 (Ym) is a conversion factor based on the STATE selected at the top of 14. Ym values are established by the EPA based on typical cow diets in different regions.

VOLATILE SOLIDS PRODUCED (VSP) is closely coupled with **Step 13** and is utilized in **Step 15**. The volatility of dairy waste is a significant factor driving GHG emissions, especially from gaseous forms of nitrogen. This equation is a function of GROSS ENERGY (GE) and DIGESTIBLE ENERGY (DE) and is drawn directly from the EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007.*

The formula for VOLATILE SOLIDS PRODUCED (VSP) is:
Where:

$$\mathrm{VSP} = \left(\frac{(\mathrm{GE} - \mathrm{DE} + (0.02 \times \mathrm{GE}))}{20.1} \right)$$

GE is the GROSS ENERGY INTAKE
DE is the DIGESTIBLE ENERGY

STEP 15. METHANE EMISSION PREDICTIONS FROM DAIRY CATTLE PER DAY

All studies of GHG emissions from dairy farm operations conclude that methane emissions are an important source of total dairy sector GHG emissions. Modules covering CO2 and N2O emmisions will be added in future enhancements, so that total global warming potential can be calculated.

Based on parameters established in S**teps 1-14, Step 15** projects methane emissions from dairy farm operations from enteric fermentation and manure generation/storage, and total methane (the sum of the two). The series of calculations in this step draw on previously computed values and require no additional input from users. As in other steps within **SOG Version 1.1**, USER REPORTED values can be incorporated instead, when available.

Subsections in **Step 15** calculate methane emissions from lactating cows, dry cows, and heifers older and younger than one year. Equations used for estimating the methane contribution from all animal types (**Steps 15.1 – 15.4**) are exactly the same, with the exception of the EPA method for methane from enteric fermentation and manure, where the equation is adjusted proportionately to the animal's body weight.

Step 15a covers Scenario 1 and Scenario 2 and **Step 15b** covers Scenario 3 and Scenario 4.

STEP 15.1. ONE LACTATING COW CONTRIBUTION

Methane emissions from a dairy animal's enteric fermentation (enteric only, from burping and passing gas) can be USER REPORTED or INTERNALLY CALCULATED based on four methods:

- daily milk production,
- amont of feed consumed (i.e., DMI),
- percent of forage in a cow's diet, or
- standard EPA Method (EPA, 2007).

Step 15a. Methane Emission Predictions from Dairy Cattle per Day

	Scenario 1 Dairy Farm 1					
Step 15a.1 One Lactating Cow Contribution						
	Converted Values					**Source No.**
Methane (CH4): (Enteric only)	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on Milk Production	○	1.121	lbs/day	0.508	kgs/day	1
- Calculated based on DMI	○	0.783	lbs/day	0.355	kgs/day	2
- Calculated based on Percent Forage	○	0.738	lbs/day	0.335	kgs/day	2
- Calculated based on EPA Method	●	0.928	lbs/day	0.421	kgs/day	3
Methane (CH4): (Manure only)	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on EPA Method	●	1.167	lbs/day	0.529	kgs/day	4
Total Methane from Lactating Cow:		**2.096**	**lbs/day**	**0.951**	**kgs/day**	

METHANE (CH_4) (ENTERIC ONLY) can be calculated four ways:

- Based on UNADJUSTED MILK PRODUCTION PER DAY (UMPD): 75% of daily unadjusted milk production (from **Step 3**), multiplied by 24.9 grams/day, divided by 1000 to convert from kg to g.

$$CH_4(EF) = \left(\frac{(UMPD(kg/day) \times 24.9(g/day))}{1000}\right) \times 75\%$$

-

- Based on DMI, where DMI is multiplied by a coefficient of 0.81, a constant of 3.23 is added, and the sum is then divided by 55.65 to convert mega joules to kilograms.

$$CH_4(EF) = \left(\frac{(DMI(kg/day) \times 0.81 + 3.23)}{55.65}\right)$$

-

- Based on PERCENT FORAGE, as established on **Step 9.1** TOTAL FORAGES for all lactating cows.

$$CH_4(EF) = \left(\frac{(\%Forage \times 0.14 + 8.56)}{55.65}\right)$$

- Based on the EPA METHOD, takes into consideration the GROSS ENERGY INTAKE (GE) and the METHANE CONVERSION FACTOR (Ym).

$$CH_4(EF) = \left(\frac{(GE \times Ym)}{55.65}\right)$$

Where:
GE = GROSS ENERGY INTAKE
Ym = PORTION OF GE CONVERTED TO CH_4
55.65 converts the values from mj to kg.

METHANE (CH_4) (MANURE ONLY) is calculated using the EPA method, which is driven off the estimate of VOLATILE SOILDS PRODUCED (VSP) from **Step 14.2** and the WASTE MANAGEMENT SYSTEM selected in **Step 14.1**. These choices, in turn, determine the WMS METHANE CONVERSION FACTOR (MCF) that is used in the below formula:

$$CH_4(manure) = VSP \text{ x } B_o \text{ x } MCF \text{ x } 0.662$$

Where:
VSP = VOLATILE SOLIDS PRODUCED
B_o = CH_4 PRODUCTING POTENTIAL OF WASTE
MCF = WMS METHANE CONVERSION FACTOR
0.662 kg m^3 is the density of CH_4 at 25°C (i.e. 77°F) (Note: CH_4 gas has a density of 1.819 kg m^3 at boiling point).

TOTAL METHANE FROM LACTATING COW is the sum of enteric methane and manure methane, from **Step 15.1.**

STEP 15.2. ONE DRY COW CONTRIBUTION (SEE ABOVE)

The CH_4 emitted from enteric fermentation from dry cows can be calculated by using three of the above equations: DMI-BASED, PERCENT FORAGE, and the EPA METHOD. The DMI equation uses the DMI given for dry cows in **Step 6.2**. Likewise, the PERCENT FORAGE based equation utilizes the percent of forages in the diet of dry cows from **Step 9.1.**

Step 15a.2 One Dry Cow Contribution						
Methane (CH4): (Enteric only)	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on DMI	○	0.462	lbs/day	0.209	kgs/day	2
- Calculated based on Percent Forage	○	0.397	lbs/day	0.180	kgs/day	2
- Calculated based on EPA Method	●	0.9284	lbs/day	0.421	kgs/day	3
Methane (CH4): (Manure only)	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on EPA Method	●	1.167	lbs/day	0.529	kgs/day	4
Total Methane from Dry Cow:		**2.096**	**lbs/day**	**0.951**	**kgs/day**	

STEP 15.3. ONE HEIFER > 1 CONTRIBUTION (SEE ABOVE)

The equations used for a heifer older than one year are exactly the same as **Step 15.2**, with one exception. The EPA METHOD calculation is adjusted proportionally to reflect the lower body weight of the heifer instead of a dry cow.

Step 15a.3 One Heifer > 1 Contribution						
Methane (CH4): (Enteric only)	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on DMI	○	0.396	lbs/day	0.179	kgs/day	2
- Calculated based on Percent Forage	○	0.385	lbs/day	0.175	kgs/day	2
- Calculated based on EPA Method	●	0.624	lbs/day	0.283	kgs/day	3,5
Methane (CH4): (Manure only)	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on EPA Method	●	0.785	lbs/day	0.356	kgs/day	4,5
Total Methane from Heifer >1:		**1.409**	**lbs/day**	**0.639**	**kgs/day**	

STEP 15.4. ONE HEIFER < 1 CONTRIBUTION (SEE ABOVE)

The equations used for a heifer less than one year old are the same as Step 15.3.

Step 15a.4 One Heifer < 1 Contribution						
Methane (CH4): (Enteric only)	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on DMI	○	0.236	lbs/day	0.107	kgs/day	2
- Calculated based on Percent Forage	○	0.358	lbs/day	0.162	kgs/day	2
- Calculated based on EPA Method	●	0.219	lbs/day	0.099	kgs/day	3,5
Methane (CH4): (Manure only)	Choose one:					
- User Reported	○	0.000	lbs/day		kgs/day	
- Calculated based on EPA Method	●	0.275	lbs/day	0.125	kgs/day	4,5
Total Methane from Heifer < 1:		**0.493**	**lbs/day**	**0.224**	**kgs/day**	

APPENDIX A – FORMULA SOURCES

APPENDIX A in **SOG Version 1.1** identifies all the INTERNALLY CALCULATED variables and formulas used in the calculator beginning with **Step 1** and progressing sequentially through **Step 15**. It also provides a narrative description of the formula/equation, and when applicable, its source. An excerpt from this Appendix appears below.

The name of each variable or formula in column one is the same as the title or header label used in the calculator where ever the variable or formula is used. The equations in column three are written out using the actual variable names and the equation semantics used in Excel commands. These variable names can also be reviewed in the CHOSEN PARAMETERS (I,II,III & IV) worksheets at the beginning of **SOG Version 1.1.** For example, the first formula determines the PERCENT OF LACTATING COWS relative to all adult cows (lactating and dry) in **Step 1.** These two variable names are also listed on the CHOSEN PARAMETERS I worksheet under **Step 3**, where the variables originated. In some instances, a generic variable name is used in an equation description.

The fourth column gives a full narrative description of each formula and the fifth column lists the source of each formula when taken from EPA or IPCC reports or published research papers.

Appendix A - Explanation and Source of Formulas Incorporated in Version 1.1 of the Calculator.

Formula Name	Step Formula Used In	Equation	Narrative Explanation	Source of Equation
Manure Excretion projected for Lactating and Dry Cow	Steps 13 & 13b	(DMI x 2.63) + 9.4	The Total Maure Excretion Projected of a Lactating Cow is the (amount of DMI (kg) times 2.63) + 9.4. The same equation is used for dry cow manure excretions.	Nennich, T. D., J. H. Harrison, et al. (2005). Prediction of manure and nutrient excretion from dairy cattle. *Journal of Dairy Science* 88(10): 3721-3733.
Manure Excretion projected for Heifer > 1	Steps 13 & 13b	(DMI_Heifer_kg x 4.158) - (Heifer_Weight x .0246)	The Total Manure Excretion projected for Heifers greater than one is the DMI (kg) required for a heifer times 4.158 minus the body weight of the heifer times 0.0246.	Nennich, T. D., J. H. Harrison, et al. (2005). Prediction of manure and nutrient excretion from dairy cattle. *Journal of Dairy Science* 88(10): 3721-3733.
Manure Excretion projected for Calf	Steps 13 & 13b	DMI_Calf_kg * 3.45	The Total Manure Excretion projected for Calfs is the DMI (kg) required for a calf times 3.45.	Nennich, T. D., J. H. Harrison, et al. (2005). Prediction of manure and nutrient excretion from dairy cattle. *Journal of Dairy Science* 88(10): 3721-3733.
Dry Matter Excretions projected (all animals except calves)	Steps 13 & 13b	(DMI (kg) x 0.356) + .80	The Dry Matter Excretion projected is the amount of DMI required per day times 0.356 plus 0.8. This equation is used for all animal types except calves.	Nennich, T. D., J. H. Harrison, et al. (2005). Prediction of manure and nutrient excretion from dairy cattle. *Journal of Dairy Science* 88(10): 3721-3733.
Dry Matter Excretions projected for Calves	Steps 13 & 13b	DMI_Calf_kg * 0.393	The Dry Matter Excretion projected for Calves is the amount of DMI required per day times 0.393.	Nennich, T. D., J. H. Harrison, et al. (2005). Prediction of manure and nutrient excretion from dairy cattle. *Journal of Dairy Science* 88(10): 3721-3733.
Nitrogen Excretion reported	Steps 13 & 13b	Unadjusted_Milk_Production_kg * 5.67(g/day) / 1000)	The Nitrogen Excretion as reported is based on daily unadjusted milk production times 5.67 grams of nitrogen per kg of milk produced per day for conventional cows. Used 5.15 (9.1% less) for conventional plus rbST cows and 8.97 for organic cows.	Capper; PNAS (2008) The environmental impact of recombinant bovine somatotropin (rbST) use in dairy production.
Nitrogen Excretion projected for Lactating and Dry Cows	Steps 13 & 13b	(DMI_Lact_Cow_kg * Dietary_CP_Lact_Cow * 84.1) + (Body_Weight_kg * 0.196)) / 1000	The Nitrogen Excretion as projected is the amount of DMI required for lactating/dry cow times the dietary crude protein times 84.1 plus the body weight of the cow times 0.196.	Nennich, T. D., J. H. Harrison, et al. (2005). Prediction of manure and nutrient excretion from dairy cattle. *Journal of Dairy Science* 88(10): 3721-3733.
Nitrogen Excretion projected for Heifers	Steps 13 & 13b	(DMI_Heifer_kg * Dietary_CP_Heifer * 78.39) + 51.4) / 1000	The Nitrogen Excretion as projected for Heifers is the amount of DMI requred for a heifer times the dietary crude protein times 78.39 plus 51.4.	Nennich, T. D., J. H. Harrison, et al. (2005). Prediction of manure and nutrient excretion from dairy cattle. *Journal of Dairy Science* 88(10): 3721-3733.

APPENDIX B-VARIABLE NAMES AND ACRONYMS

All variables in this Users Manual are listed alphabetically by acronyms in Appendix B. This table also lists the Step in the calculatior where each variable is introduced and defined.

ABBRE-VIATION	DESCRIPTION	WHERE FOUND
#YCP	NUMBER OF YEARS A COW IS PRODUCTIVE	4.4
%DD	PERCENT DIET DIGESTIBILITY	14.1
%DMI	PERCENT DRY MATTER INTAKE	9
ABAPC	AVERAGE BREEDING ATTEMPTS PER CONCEPTION TO TERM	4.1
ACEPL	AGE OF COW AT END OF PRODUCTIVE LIFE	4.4
ACPCL	ANNUAL CALF PRODUCTION DURING A COW'S LIFE	5.2
AHFB	AGE OF HEIFER AT FIRST BIRTHING	4.3
AHFBA	AGE OF HEIFER AT FIRST BREEDING ATTEMPT (MONTHS)	4.1
AI	ARTIFICIAL INSEMINATION	4
AMPYL	AVERAGE MILK PRODUCTION PER YEAR OF LLIFE	5.1
BN	BULLS NEEDED	1.4
BO	CH_4 (METHANE) PRODUCING POTENTIAL OF WASTE	14
CI	CALVING INTERVAL	4.3
CPLACT	CALF PRODUCTION PER LACTATION	4.3
CPPL	CALF PRODUCTION IN PRODUCTIVE LIFE	4.3
CRDC	CULL RATE FOR DRY COWS	1.2.2
D	DEFAULT	OVERVIEW
DC	PERCENT DRY COWS	1.1
DCP	DIETARY CRUDE PROTEIN	12
DCOLC	DRY COWS AS A PERCENT OF ONE LACTATING COW	1.1
DDRLP	DEATH AND DOWNER RATE FOR LACTATING COWS	1.2.1
DE	DIGESTIBLE ENERGY	14.2
DIM	DAYS IN MILK	3
DLDM	DAYS IN LACTATION WITH DIVERTED MILK	4.4
DME	DRY MATTER EXCRETION	13.A.1
DMI	DRY MATTER INTAKE	6.1
DK	DIETARY POTASSIUM	12
DLDM	DAYS IN LACTATION WITH DIVERTED MILK	4.4
DME	DRY MATTER EXCRETION	13.A.1
DMI	DRY MATTER INTAKE	6.1
DMIMP	DRY MATTER INTAKE AT UNADJUSTED MILK PRO-DUCTION LEVEL (DAYS)	6.1

ABBRE-VIATION	DESCRIPTION	WHERE FOUND
DMIPPM	DRY MATTER INTAKE PER POUND OR KG MILK	6.1
DMP	DAILY MILK PRODUCTION	3
DNBA	DAYS TO NEXT BREEDING ATTEMPT	4.2
DP	DIETARY PHOSPHORUS	12
DRDC	DEATH RATE FOR DRY COWS	1.2.2
DRH	DEATH RATE FOR HEIFERS > 1 YEAR OLD	1.3.1
DRRRF	REASONS AND RISK FACTORS FOR DEATH AND DOWNER RATES	2.2
DRUH	DEATH RATE FOR UNWEANED HEIFERS	1.3.3
DRWH	DEATH RATE FOR WEANED HEIFERS	1.3.2
ECM	ENERGY CORRECTED MILK	3
ECMPD	ENERGY CORRECTED MILK PER DAY	3
ELDNBA	AVERAGE DAYS TO NEXTBREEDING ATTEMPT FOR COWS WITH EMBRYONIC LOSS (DAYS 1-40)	4.2
FBR	FAILURE TO BREED	4.1
GE	GROSS ENERGY INTAKE	14.2
GP	GESTATION PERIOD	4.3
H<1P	HEIFERS <1 YEAR AS A PERCENT OF ONE LACTAT-ING COW	1.3.2
HAR	HEIFER ABORTION RATE	4.2
HFBR	HEIFER FAILURE TO BREED RATE	1.3.1
IC	INTERNALLY CALCULATED	OVERVIEW
ICRLC	INVOLUNTARY CULL RATE FOR LACTATING COWS	1.2.1
KE	POTASSIUM EXCRETION	13.A.1
LDP	LENGTH OF DRYOFF PERIOD	3
LOL	LENGTH OF LACTATION (DAYS)	3
MCF	WMS METHANE CONVERSION FACTOR	14.1
ME	MANURE EXCRETION	13.A.1
MERYOL	MEAT REVENUE PER YEAR OF LIFE	5.4
MIRYOL	MILK REVENUE PER YEAR OF LIFE	5.3
MOB	METHOD OF BREEDING	4
MPCCL	MEAT PRODUCTION FROM CALVES IN A COW'S LIFE	5.2
MQ	MILK QUALITY	3
MRCSS	MEAT REVENUE BASED ON CALF SALES OR SLAUGHTER	5.4
MVBC	MARKET VALUE FOR BULL CALVES	5.5
MVHC	MARKET VALUE FOR HEIFER CALVES	5.5
NCB	NUMBER OF COWS PER BULL	1.4

ABBRE-VIATION	DESCRIPTION	WHERE FOUND
NDBBA	NUMBER OF DAYS BETWEEN BREEDING AT-TEMMPTS	4.1
NDCFBA	NUMBER OF DAYS FROM CALVING TO FIRST BREED-ING ATTEMPT	4.1
NE	NITROGEN EXCRETION	13.A.1
NE(A)	NET ENERGY FOR ACTIVITY	14.2
NE(L)	NET ENERGY FOR LACTATION	14.2
NE(M)	NET ENERGY FOR MAINTENANCE	14.2
NE(P)	NET ENERGY FOR PREGNANCY	14.2
NH<1N	NUMBER OF HEIFERS > 1 YEAR NEEDED	1.3.2
NH>1NPR	NUMBER OF HEIFERS > 1 YEAR NEEDED TO PRO-DUCE REPLACEMENTS	1.3.2
NHNB	NUMBER HEIFERS THAT NEED TO BE BORN	1.3.3
NOL	NUMBER OF LACTATIONS	4
NRHNSH	NUMBER OF REPOLACEMENT HEIFERS NEEDED TO SUSTAIN HERD	1.2.3
OLC	ONE LACTATING COW	1.1
PAOLC	PERCENT OF ANIMAL PER ONE LACTATING COW	9
PCAS	PORTION OF COW AVAILABLE FOR SLAUGHTER	5.2
PCFT	PERCENT OF COWS FAILING TO GO TO TERM	4.2
PCSNC	PERCENT OF COWS SERVED BUT NO CONCEPTIONS	4.2
PE	PHOSPHORUS EXCRETION	13.A.1
PELR	PERCENT OF COWS EXPERIENCING EMBRYONIC LOSS	4.2
POUNDS AI	POUNDS OF ACTIVE INGREDIENT	11
PPM	PRICE PER POUND OF MILK	5.3
PPMDMI	POUNDS OR KG UNADJUSTED MILK PRODUCTION PER KG DRY MATTER INTAKE	6.1
PPPCALF	PRICE PER POUND (CALF)	5.4
PPPCOW	PRICE PER POUND (COW)	5.4
PSAR	PERCENT OF COWS SERVED EXPERIENCING SPON-TANEOUS ABORTION	4.2
RCS	REVENUE FROM CALVES SOLD	5.5
REM	RATIO OF ENERGY FOR MAINTENANCE	14.2
RFIC	REASONS FOR INVOLUNTARY CULLING	2.1
RFVC	REASONS FOR VOLUNTARY CULLING	2.1
SADNBA	AVERAGE DAYS TO NEXT BREEDING ATTEMPT FO COWS CONCIEVED WITH CALF LOSS BETWEEN DAYS 41-260 (SPONTANEOUS ABORTION)	4.2

ABBRE-VIATION	DESCRIPTION	WHERE FOUND
TDDMI	TOTAL DAILY DRY MATTER INTAKE	9
TMPCL	TOTAL MILK PRODUCTION IN A COWS LIFE	5.1
TMR	TOTAL MIXED RATION	6
TNE	TOTAL NET ENERGY	14.2
TRNDC	TOTAL REPLACEMENTS NEEDED FOR DRY COWS	1.2.2
TRNL	TOTAL REPLACEMENTS NEEDED FOR LACTATING COWS	1.2.1
UMPD	UNADJUSTED MILK PRODUCTION PER DAY	3
UR	USER REPORTED	OVERVIEW
VCRLC	VOLUNTARY CULL RATE FOR LACTATING COWS	1.2.1
VSP	VOLATILE SOLIDS PRODUCED	14.2
WMS	WASTE MANAGEMENT SYSTEM	14.1
YM	PORTION OF GROSS ENERGY INTAKE COVERTED TO METHANE	14.2
	GENERAL ABBREVIATIONS	
EPA	ENVIRONMENTAL PROTECTION AGENCY	
GHG	GREENHOUSE GASES	
IPCC	INTERGOVENMENTAL PANEL ON CLIMATE CHANGE	
SOG	SHADES OF GREEN	
CH_4	METHANE	
N_2O	NITROUS OXIDE	
CO_2	CARBON DIOXIDE	
MJ	MILLIJOULE	
KG	KILOGRAM	
LB	POUND	

APPENDIX C – OPTIONS WORKSHEET

Throughout **SOG Version 1.1**, users have the opportunity to chose USER REPORTED, DEFAULT or INTERNALLY CALCULATED values by selecting the associated radio button. These selections are records on the OPTIONS worksheet in the Excel file and are internally used by the calculator.

The OPTIONS worksheet should not be edited in anyway, shape or form! It is the driving force of the calculator. For this reason, Rows 2 – 105 in the OPTIONS worksheet are compressed from viewing to avoid accidental tampering with the structure of this page. Any changes, even very minor, to this page could impair the functionality of the calculator.

APPENDIX D – DEFAULTS

The DEFAULTS worksheet in **SOG Version 1.1** lists all the default values and their sources that are used to initialize the calculator. These DEFAULT values can also be selected for use in a given scenario or application, and relied upon in the absence of USER REPORTED or INTERNALLY CALCULATED values. These values are set to common industry values, or have been derived from, or based upon the results of recent industry or USDA surveys, published research reports, EPA reports, or reports issued by the IPCC.

The DEFAULT values for each step are organized into tables for ease of use. The source for each DEFAULT is documented either on the far right column, or at the bottom of each table. The default values for **SOG Version 1.1** of the calculator are as follows:

Defaults for Step 1			
Variable Name	**Default Value**	**Source**	
Cull Rate for Lactating Cow	23.6%	Dairy 2007 p. 87	
Cull Rate for Dry Cow	2.0%	Extrapolated from Dairy 2007, p. 87	
Death Rate for Lactating Cow	5.7%	Dairy 2007 p. 91	
Death Rate for Dry Cow	5.7%	Dairy 2007 p. 91	
Death Rate for Heifers >1	1.8%	Dairy 2007 p. 91	
Death Rate for Weaned Heifers (<1)	1.8%	Dairy 2007 p. 91	
Unweaned Heifer Death Rate	7.8%	Dairy 2007 p. 91	
Default Body Weights in kgs (Step 1)			
Breed:	Holstein	Jersey	Crossbreed
Lactating Cow	650	400	525
Dry Cow	755	500	625
Heifer >1	437	275	350
Heifer <1	153	100	125
Grown Calf Weight	700	450	575
Source: Lactating Cow weights for Holsteins and Jerseys per Dairy 2007. Other Holstein			

Defaults for Step 3		Source
Gestation Period	282	
Dryoff Period	57.8	Dairy 2007 p.26
Unadjusted Milk Production (pounds per day)	60	

Defaults for Step 4		Source
Days from Calving to First Breeding Attempt	60	
Age at First Birthing	25.2	Dairy 2007 p. 23
Percent of Conceptions that Produce Heifer Calves	50.8%	Dairy 2007 p. 61
Percent of Conceptions that Produce Bull Calves	49.2%	Dairy 2007 p. 61
Days in Lactation with Diverted Milk	5	The Organic Center

Input Variables Values from Dairy 2007 Survey Effected by Breeding Method (Step 4)				Source No.
Breeding Method:	**Bull**	**AI with Sync**	**AI wo/ Sync**	
Adult Cow Defaults				
Failure to Breed Rate	55%	35%	45%	
Breeding Attempts from Conception to Term	1.4	2.475	2.8	
Number of Days Between Attempted Breedings	32	40	36	
Unsuccessful Breeding Attempts Rate	58%	50%	50%	
Unsuccessful Breeding Attempts (Days between attempts)	30	30	30	
Embryonic Loss Rate	9%	16%	13%	
Embryonic Loss (Days Between Attempts)	60	60	60	
Spontaneous Abortion Rate	3%	4.5%	4.2%	2
Spontaneous Abortion (Days Between Attempts)	100	100	100	
Percent of Conceptions that are Live Births	94%	86%	88%	
Number of Cows One Bull Can Impregnate	25	40	40	
Heifer Defaults				
Age at First Breeding	12.65	12.65	12.65	1
Failure to Breed Rate	15%	15%	15%	
Breeding Attempts from Conception to Term	1.4	2.475	2.8	
Number of Days Between Attempted Breedings	32	40	36	
Unsuccessful Breeding Attempts Rate	58%	50%	50%	
Unsuccessful Breeding Attempts (Days between attempts)	30	30	30	
Embryonic Loss Rate	9%	16%	13%	
Embryonic Loss (Days Between Attempts)	60	60	60	
Spontaneous Abortion Rate	3.3%	3.3%	3.3%	
Spontaneous Abortion (Days Between Attempts)	100	100	100	
Sources:				
1. Calculated to comply with other default values				
2. 5% per Dairy 2007 p.81				

Default Values for DMI Required by Animal Type (Step 6)								
Animal Type	Body Weight (kg)	DIM (kg)	Milk Production (kg)	DMI (kg)	Dietary CP (Crude Protein) (g/g of DM)	Dietary P (Phosphorpous) (g/g of DM)	Dietary K (Potassium) (g/g of DM)	Notes
Lactating Cow	630	172	31.4	21.7	0.175	0.0044	0.0129	Dietary P & K assume same as Mineral Cow
Lactating Cow w/ mineral info	617	165	31.5	21.9	0.0355	0.0044	0.0129	
Early Lactating Cow	591	38	66.5	18.2		0.0046	0.0157	
Dry Cow	755			10.4	0.133	0.0044	0.0129	Dietary P & K assume same as Mineral Cow
Heifer	437			8.34	0.112	0.0029	0.0147	
Calf	152.8			3.37	0.166	0.0037	0.0147	Dietary K assume same as Heifer
Notes: Where cell is blue, values were not given by Nennich and therefore assumed based on similar data as specified.								
Source: Nennich, J. Dairy Science, Vol 88: 3721-3733.								

APPENDIX E – METHANE CONVERSION FACTORS FOR WET AND DRY SYSTEMS

Methane Conversion Factors for Wet Systems, Percent Diet Digestibility and Ym by State for Dairy Animals (Step 14)						
Index	State	Anaerobic Lagoon	Liquid/Slurry and Deep Pit	% Diet Digestibility	Ym	Region
1	AK	0.5	0.15	65%	5.8%	West
2	AL	0.76	0.42	59%	5.6%	SE
3	AR	0.76	0.38	62%	5.7%	South Central
4	AZ	0.8	0.62	65%	5.8%	West
5	CA	0.74	0.35	69%	4.8%	California
6	CO	0.66	0.22	74%	5.8%	N Great Plains
7	CT	0.69	0.25	65%	5.8%	NE
8	DE	0.74	0.32	65%	5.8%	NE
9	FL	0.79	0.54	59%	5.6%	SE
10	GA	0.77	0.41	59%	5.6%	SE
11	HI	0.77	0.59	65%	5.8%	West
12	IA	0.71	0.27	65%	5.8%	Midwest
13	ID	0.69	0.25	65%	5.8%	West
14	IL	0.74	0.32	65%	5.8%	Midwest
15	IN	0.73	0.29	65%	5.8%	Midwest
16	KS	0.75	0.33	74%	5.8%	N Great Plains
17	KY	0.76	0.35	59%	5.6%	SE
18	LA	0.79	0.47	62%	5.7%	South Central
19	MA	0.67	0.24	65%	5.8%	NE
20	MD	0.73	0.31	65%	5.8%	NE
21	ME	0.62	0.2	65%	5.8%	NE
22	MI	0.69	0.25	65%	5.8%	Midwest
23	MN	0.68	0.25	65%	5.8%	Midwest
24	MO	0.75	0.34	65%	5.8%	Midwest
25	MS	0.78	0.44	59%	5.6%	SE
26	MT	0.63	0.21	74%	5.8%	N Great Plains
27	NC	0.75	0.34	59%	5.6%	SE
28	ND	0.66	0.23	74%	5.8%	N Great Plains
29	NE	0.72	0.29	74%	5.8%	N Great Plains
30	NH	0.64	0.21	65%	5.8%	NE
31	NJ	0.72	0.29	65%	5.8%	NE
32	NM	0.73	0.3	65%	5.8%	West
33	NV	0.71	0.27	65%	5.8%	West
34	NY	0.66	0.23	65%	5.8%	NE
35	OH	0.71	0.28	65%	5.8%	Midwest
36	OK	0.77	0.39	62%	5.7%	South Central
37	OR	0.63	0.21	65%	5.8%	West
38	PA	0.7	0.26	65%	5.8%	NE
39	RI	0.7	0.26	65%	5.8%	NE
40	SC	0.78	0.41	59%	5.6%	SE
41	SD	0.7	0.26	74%	5.8%	N Great Plains
42	TN	0.76	0.35	59%	5.6%	SE
43	TX	0.78	0.43	62%	5.7%	South Central
44	UT	0.69	0.25	65%	5.8%	West
45	VA	0.73	0.3	59%	5.6%	SE
46	VT	0.63	0.21	65%	5.8%	NE
47	WA	0.63	0.21	65%	5.8%	West
48	WI	0.68	0.24	65%	5.8%	Midwest
49	WV	0.72	0.28	59%	5.6%	SE
50	WY	0.63	0.2	74%	5.8%	N Great Plains

Source: EPA; Annex 3.1 Methodology for Estimating Emissions of CH4, N2O, and Indirect Greenhouse Gases from Stationary Combustion. Table A-175: Methane Conversion Factors for Wet Systems by State; Table A-161: DE Values and Representative Regional Diets for the Supplemental Diet of Grazing Beef Cattle; Table A-163 Regional CH4 Conversion Rates (Ym) for Dairy Cows

Methane Conversion Factors (percent) for Dry Systems (Step 14)			
Waste Management System	**Cold**	**Temperate**	**Hot**
Composting - Static Pile	0.005	0.005	0.005
Composting - Intensive	0.005	0.01	0.015
Daily Spread	0.001	0.005	0.01
Dry Lot	0.01	0.015	0.05
Deep Pit	0	0	0
Pasture	0.01	0.015	0.015
Solid Storage	0.02	0.04	0.05
Source: EPA; Annex 3.1 Methodology for Estimating Emissions of CH4, N2O, and Indirect Greenhouse Gases from Stationary Combustion. Table A-174: Methane Conversion Factors for Dry Systems			

Other Defaults Needed to Calculate Methane Gas Emissions (Step 14)		
CH4 Producing Potential of Waste (Bo):	0.24	1
Source: EPA; Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chpt 3.10. Methodology for Estimating CH4 and N2O Emissions from Manure Management Table A-170: Waste Characteristics Data (for Dairy Cows)		

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