SHADES OF GREEN USERS MANUAL

GUIDE AND DOCUMENTATION FOR A DAIRY FARM MANAGEMENT SYSTEM CALCULATOR

SHADES OF GREEN
VERSION 1.1
OCTOBER 2010

THE ORGANIC CENTER - BOULDER COLORADO

CHECK FOR UPDATES AT: WWW.ORGANIC-CENTER.ORG/SOG_HOME

TABLE OF CONTENTS

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
Michael Hansen, Consumer Policy Institute, Consumers Union, Yonkers, New York
Carlo Leiffert, Director, Food, Quality, and Heath Network, University of Newcastle, Newcastle, U.K.
Mary-Howell Martens, Lakeview Organic Grain, Penn Van, New York
Klaas Martens, Kandmh Farm, Penn Van, New York
Laura Paine, Department of Agriculture, Trade, and Consumer Protection, Madison, Wisconsin
David Panofsky, Department of Natural Resources, Madison, Wisconsin
Lisa Petkewitz, Landsingburgh Veterinarian Hospital, Albany, New York
Guy Jodarski, Veterinarian, Organic Valley, La Farge, Wisconsin
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 Dry Cow Heifer > 1 Heifer < 1	100% 16% 44% 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.