RuFaS
Ruminant Farm Systems Model

The Next Generation of Whole Farm Modeling

What is RuFaS?

A Next-Generation, Whole-Farm, Dairy Sustainability Simulation Model

- Simulates dairy farm production and environmental impact
- Identifies ways to improve efficiency and sustainability
- Has a range of applications, from a research tool for scientists to a decision-aid tool for the dairy industry
- Coding emphasizes transparency and accessibility to ensure model flexibility, clarity, adaptability, and persistence

Many models are already out there

- Dairy contributions to climate change are widely discussed but difficult to measure.
- Companies and NGOs need tools to quantify dairy farm emissions and help suppliers achieve net zero emissions.
- Existing models do not capture the complex dynamics on dairy farms, so confusion and mistrust has arisen among dairy industry users.

TRUTERRA

CFT

DSSAT

AMTS

Integrated Farm System Model
Version 4.5

USDA / Agricultural Research Service
Pasture Systems and Watershed Management Research Unit
University Park, Pennsylvania

FARMERS ASSURING FARM RESPONSIBLE MANAGEMENT

FARM Environmental Stewardship
Version 2 Updates

SWAT Soil & Water Assessment Tool

COMET Farm | USDA United States Department of Agriculture Natural Resources Conservation Service | Colorado State University | Whole Farm and Ranch Carbon and Greenhouse Gas Accounting System.

Founders

Key Stakeholders

USDA

Cornell University

University of Arkansas

UC Davis University of California

University of South Dakota

Innovation Center for U.S. Dairy — Healthy People • Healthy Products • Healthy Planet

Wisconsin University of Wisconsin–Madison

The Nature Conservancy

WWF

NEAFA Northeast Agribusiness & Feed Alliance — Advocate · Educate · Collaborate

General Mills — Making Food People Love

DMI Dairy Management Inc.™

Evolution

2017

Formalized vision and established principles for RuFaS development

2018

Computer simulation structure established, and first lines of code written

Submitted first federal proposal

Expanded collaborators to include Cornell

2019

First paper published

Formalized documentation and version control methods

Submitted first successful Federal proposal

2020

Formalized Industry Advisory Council

Connected nutrient cycle in biophysical model

2021

Published 2 manuscripts on Animal Module

Hired first Professional Software Engineer

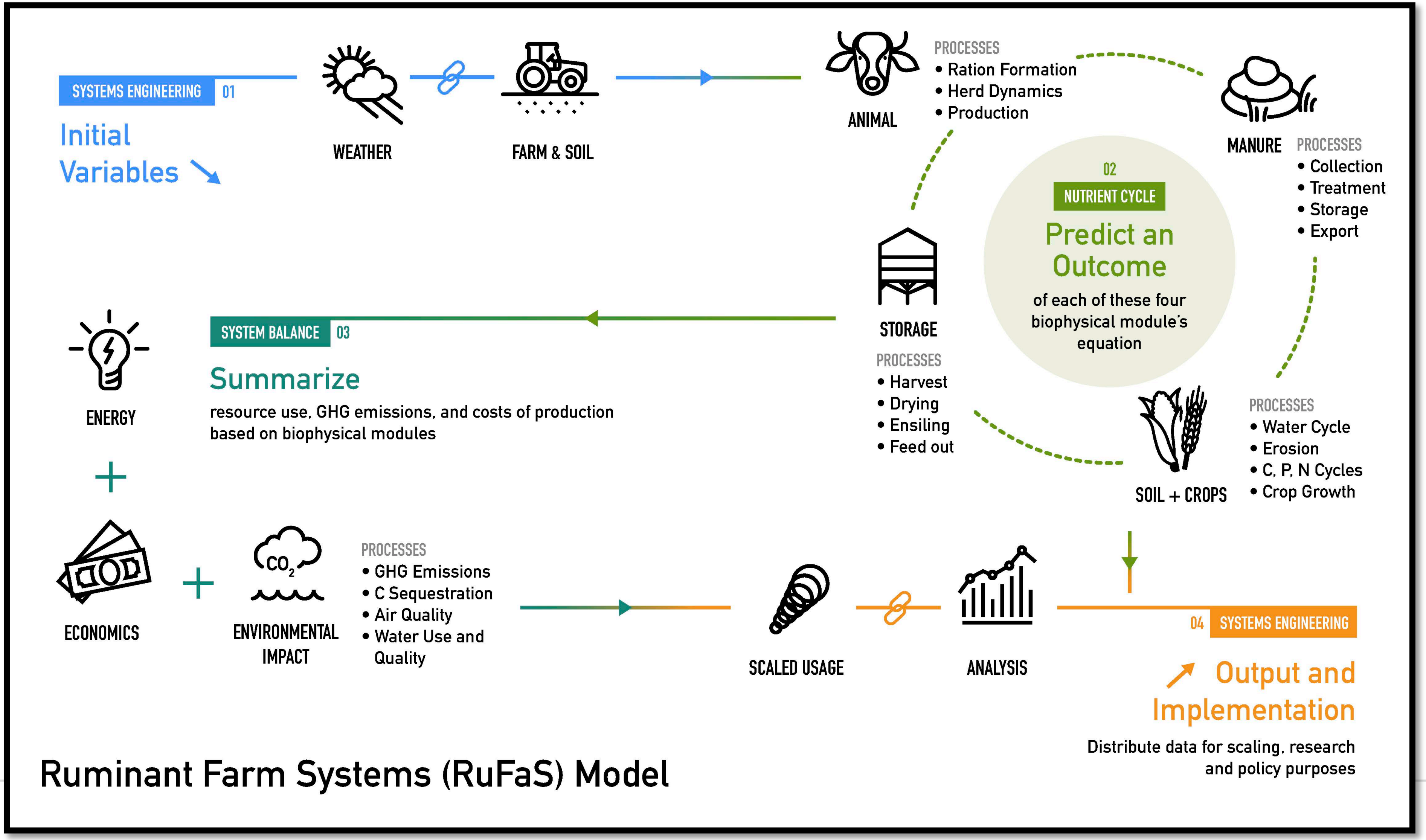
RuFaS Goals

- Interoperable
- Documented
- Open Source
- Sustainable

Participatory Modeling

- Involves stakeholders in all parts of the model development
    - 2020: Stakeholder Advisory Council
- Creates a shared understanding of the system, the problem and the solutions
- Increases stakeholder ownership of the research outcomes

How Does RuFaS Work?



RuFaS
"Feed Print"

- Combination of outputs from:
  - Crop and Soil Module
  - Animal Module
  - Systems Balance Module

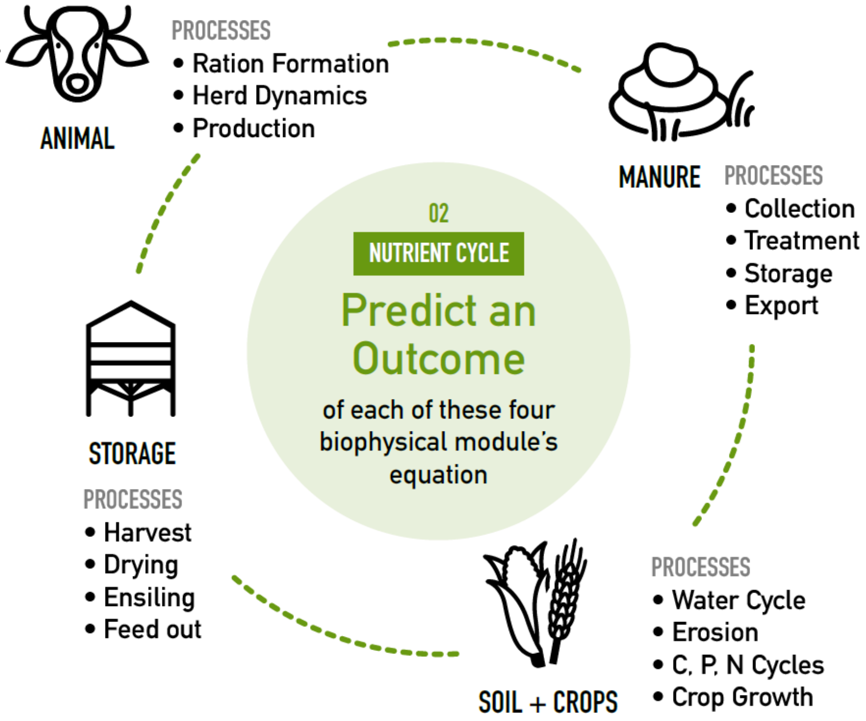
Feed Print Breakdown

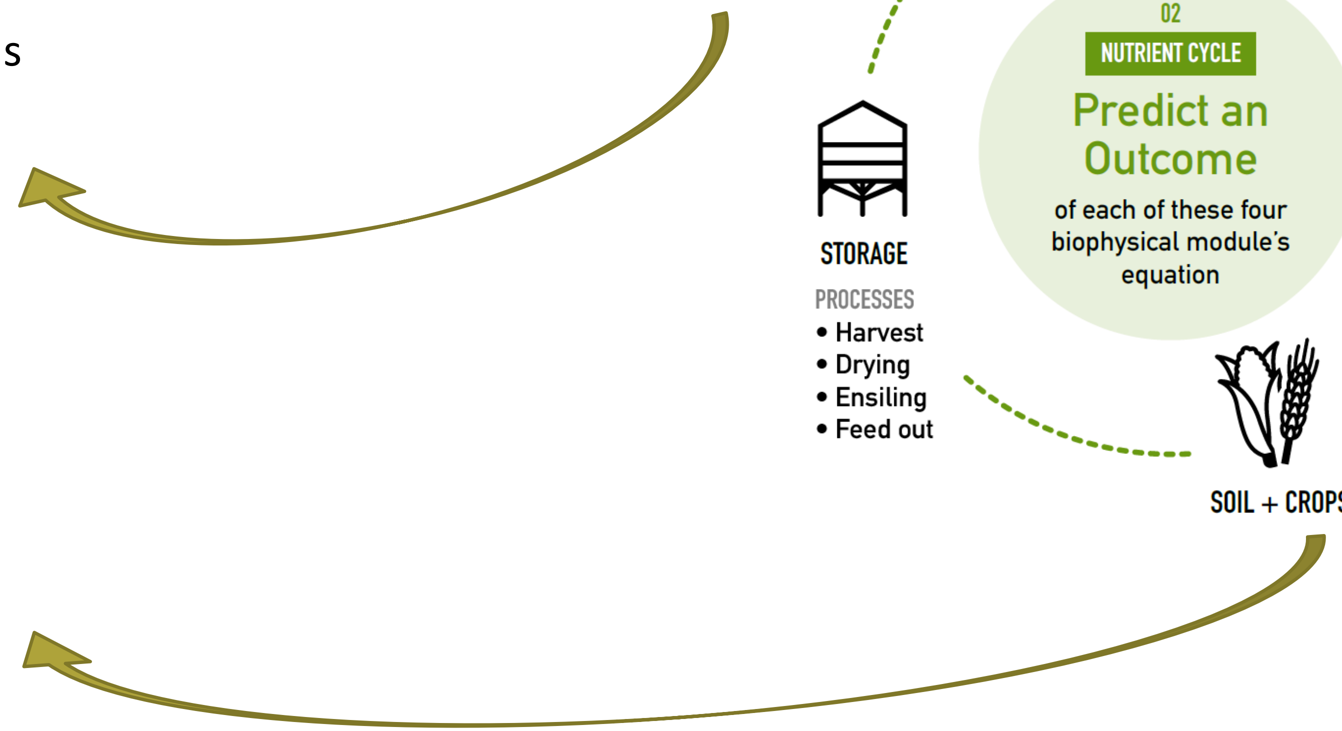
Purchased Feeds

- Embedded emissions
- Embedded Water Footprint

Farm Grown Feeds

- Soil Emissions
- Runoff
- Leaching
- Soil Carbon





Feed Print Breakdown

Farm Grown Feeds

- Field Operation Energy Use
- Embedded emissions in fertilizer not accounted for

SYSTEM BALANCE

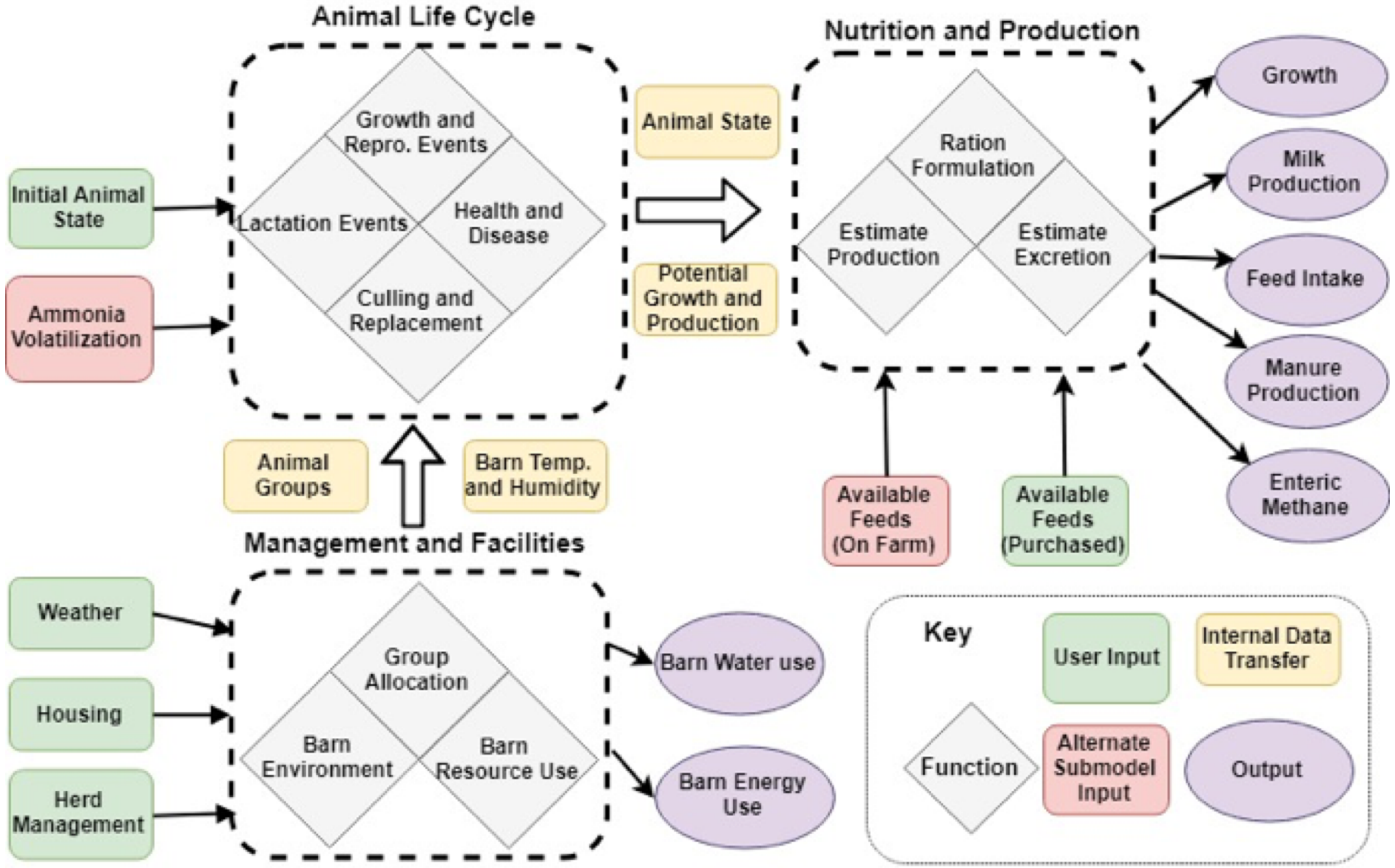
Summarize

resource use, GHG emissions, and costs of production based on biophysical modules

ENERGY

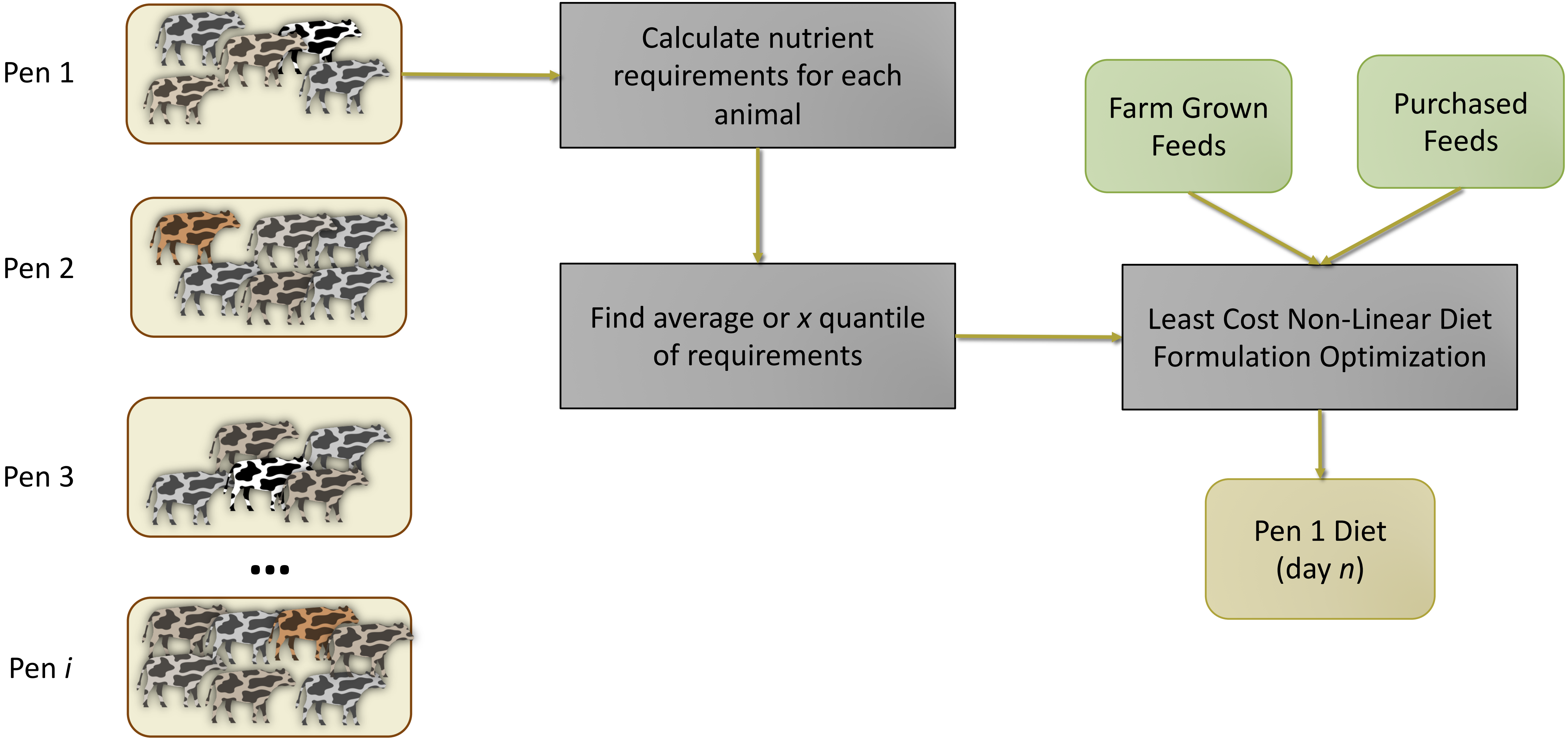
Purchased Feed Contributions to Feed Print

Diet Formulation and Collaborations with FoodS^3 Group



Animal Module

Animal Grouping and Diet Formulation

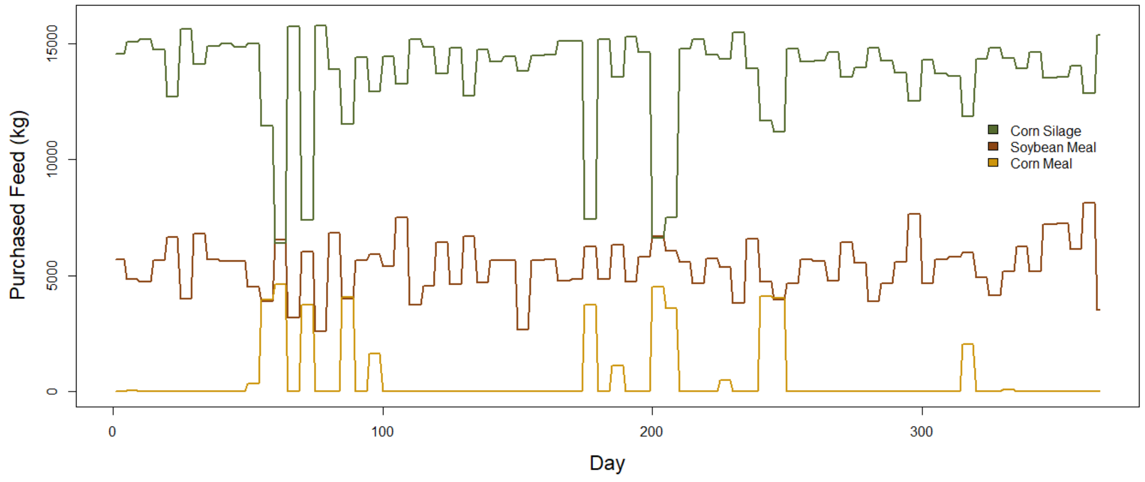


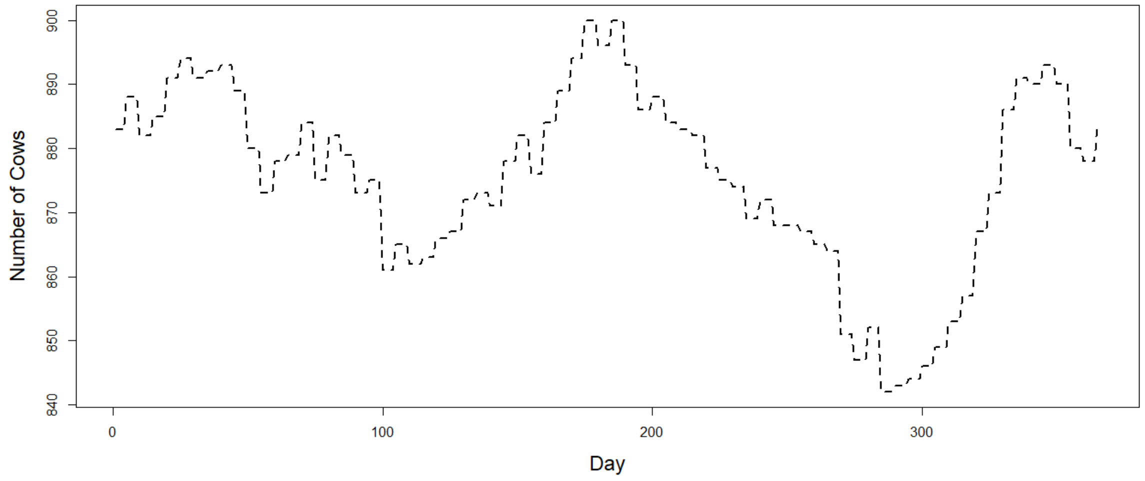
Happens on an interval set by the user (i.e. 1x/week; 1x/month)

Ration Formulation Outputs

- Pen level deliveries of all feeds
  - Based on # of animals in pen and targeted refusal rate
  - Daily estimates of feed use

- Currently collection of refusals is not represented
  - On the ‘To-do’ list





Embedded Emissions of Purchased Feed: FoodS^3 Collaboration

<u>8 of the most important dairy feeds</u>

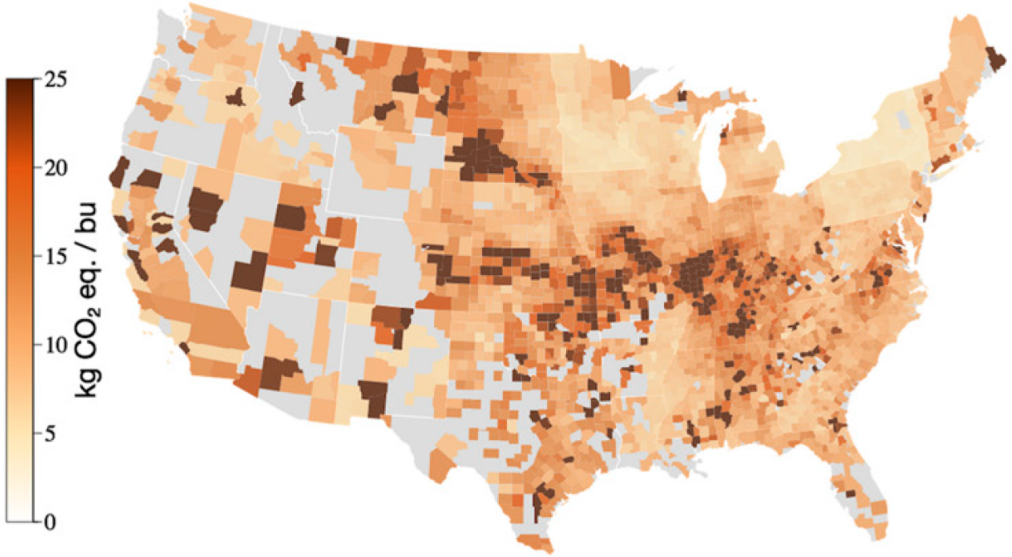
- Corn grain
- Corn Silage
- DDGS
- Soybean meal
- Wheat
- Wheat middlings
- Alfalfa hay
- Alfalfa Silage

<u>Geographically specific footprints</u>

<u>Two options for use of data:</u>

1. Origin not known- use FoodS^3 average based on location of purchase
2. Origin known – use FoodS^3 value for county of origin

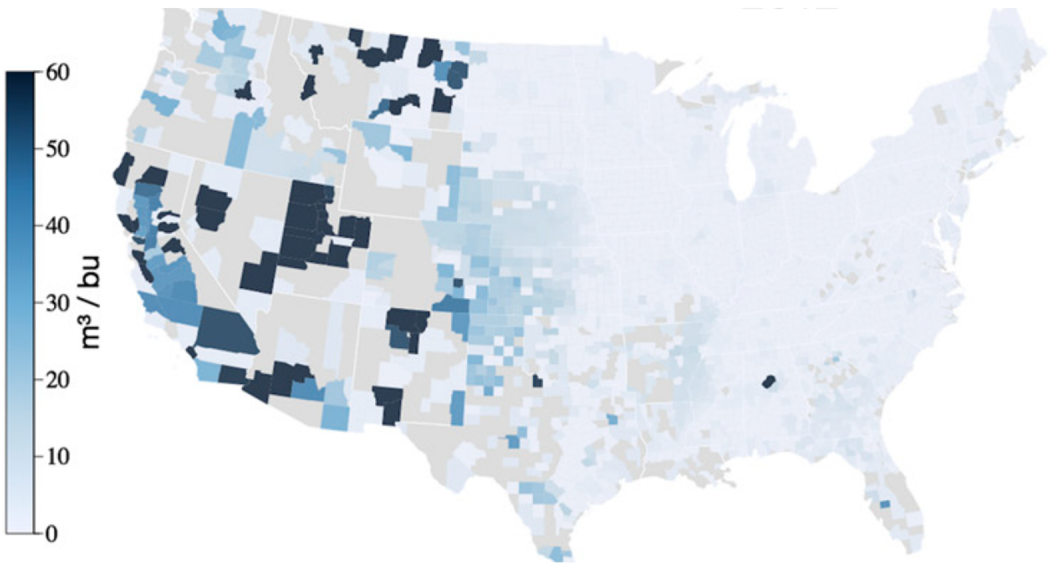
Carbon Footprint



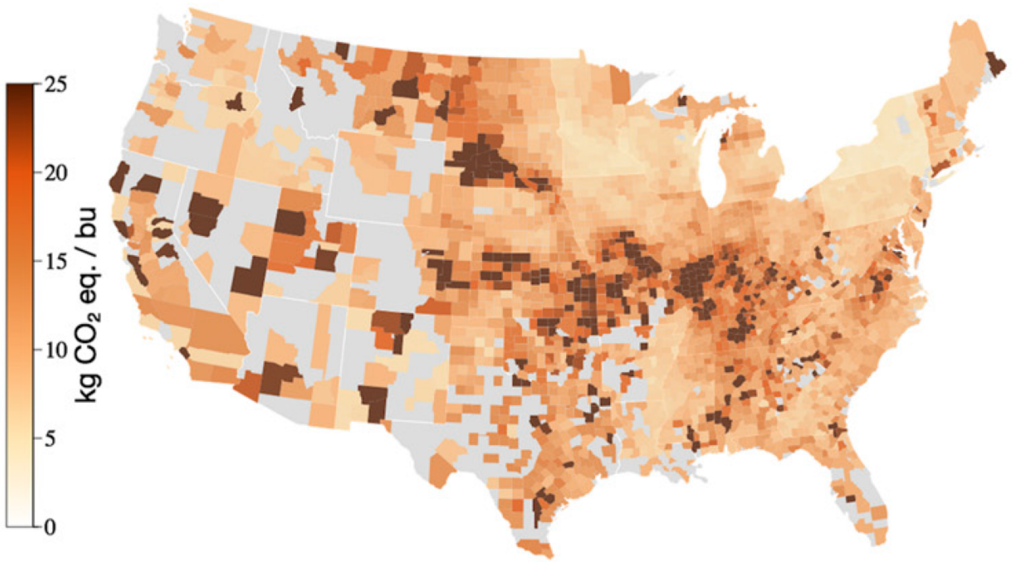
https://doi.org/10.1073/pnas.1703793114

Embedded Emissions of Purchased Feed: FoodS^3 Collaboration

Blue Water Use



Carbon Footprint

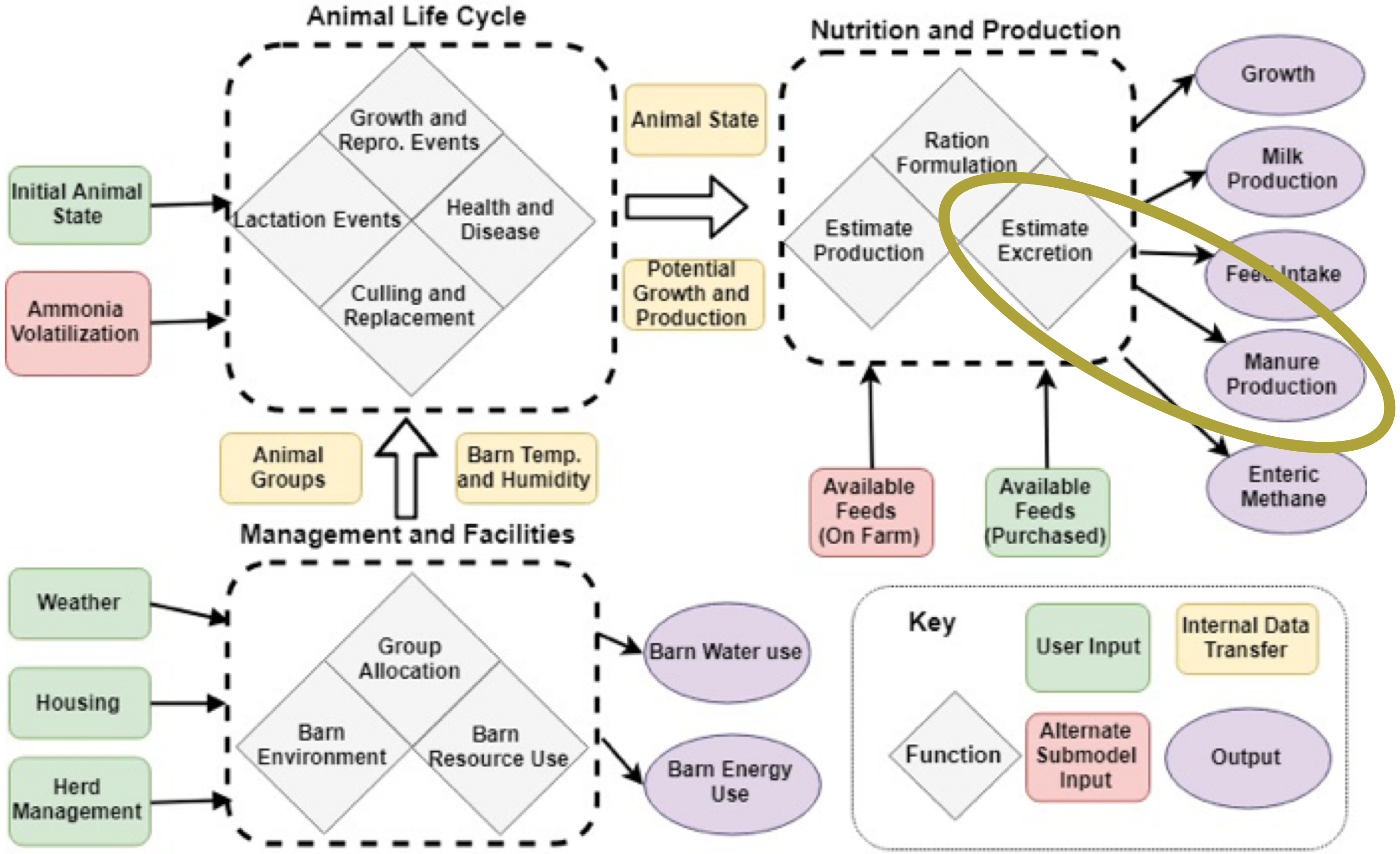


https://doi.org/10.1073/pnas.1703793114

Embedded Emissions of Purchased Feed: Other Feeds

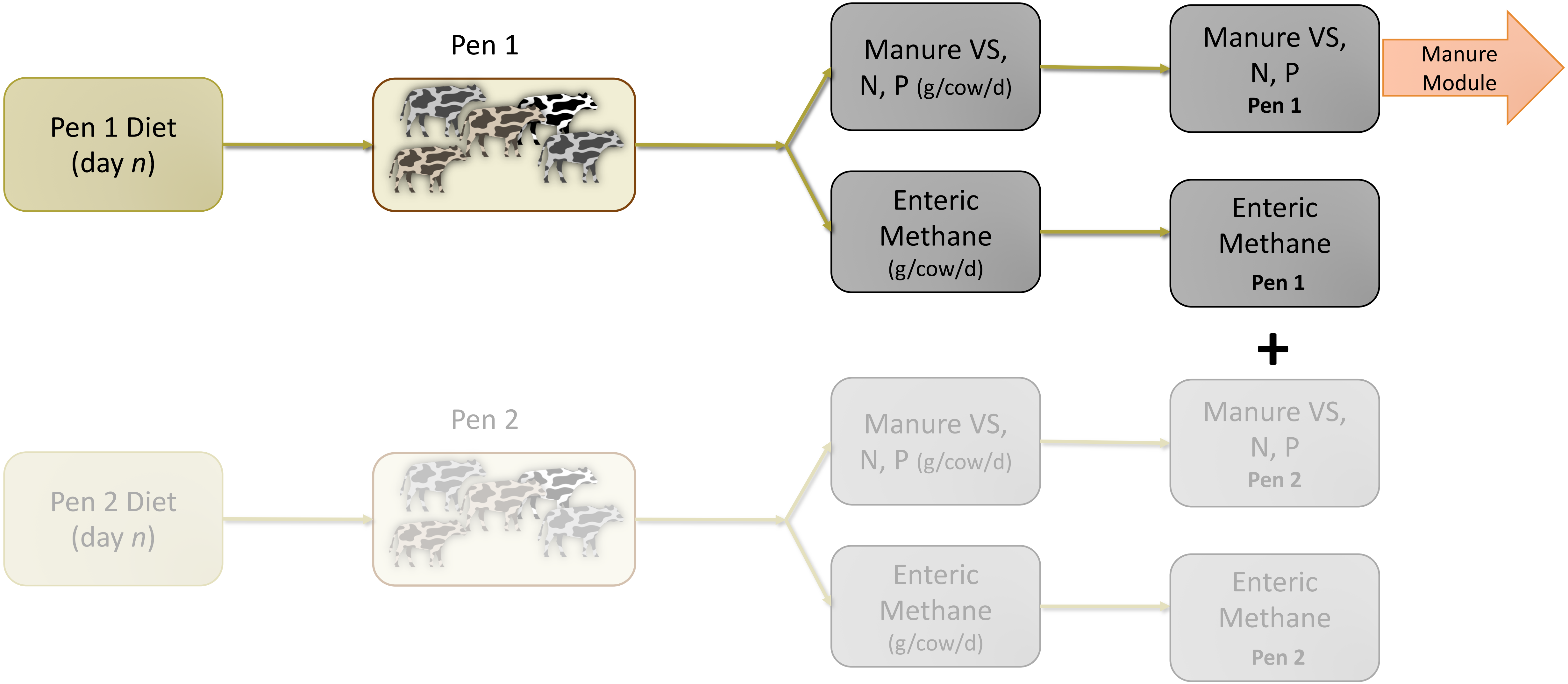
- National, Regional, or State Level Estimates
  - Depending on data availability
- Currently have emissions estimates for:
  - Almond Hulls
  - Canola Meal
  - Tomato Pomace
  - Bakery
  - Oats
  - Peanut Meal
  - Cottonseed

Short segue to manure…



Animal Module

Methane and Manure Production



Manure Excretion

- Individual Animal Excretion
- Aggregated by Pen
- Pen manure aggregated by management system at time of collection

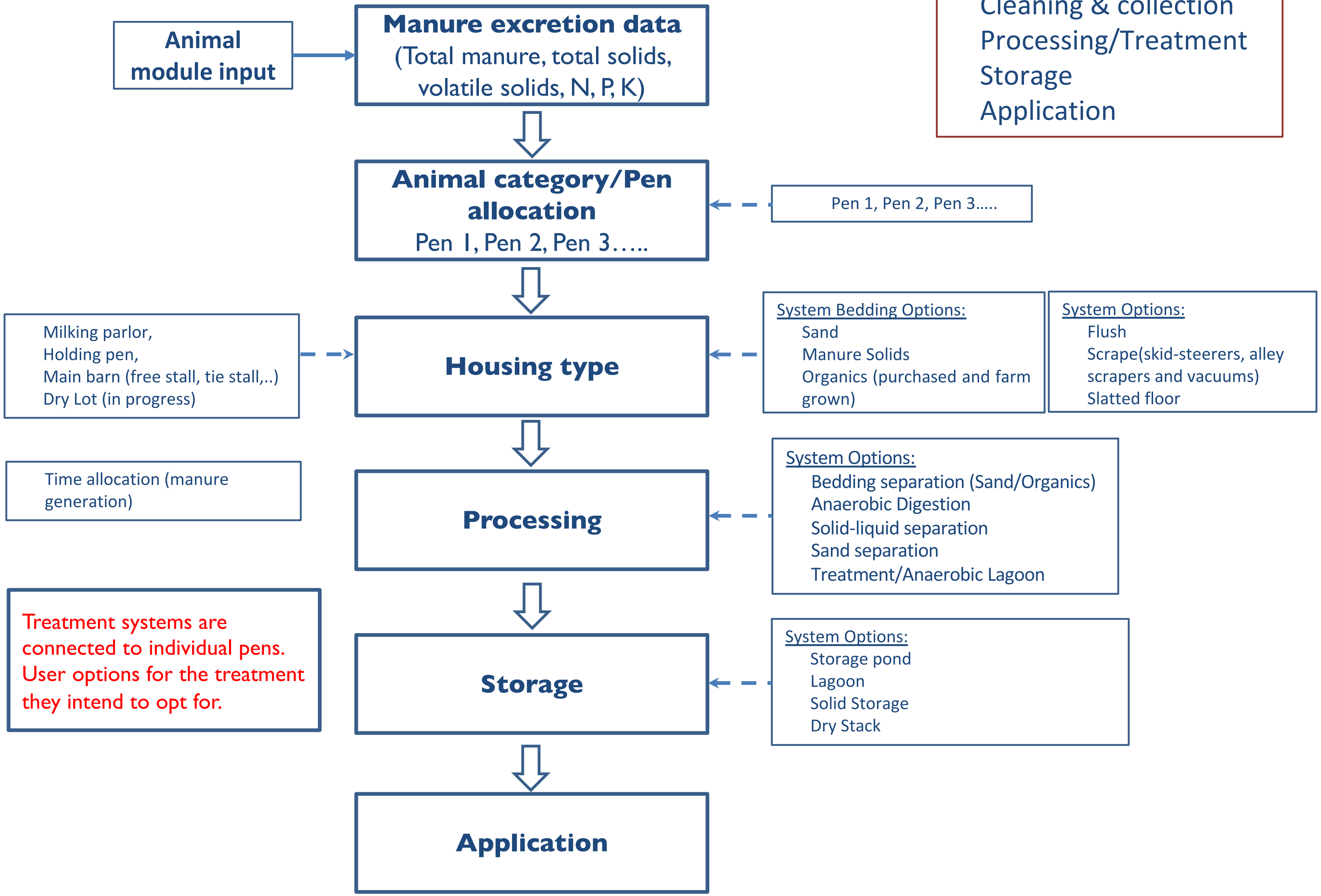
<u>Composition</u>

- Total Solids
- Volatile Solids
  - Degradable
  - Non-degradable
- Total N
- Ammoniacal N
- Urea
- Total P
- Water Soluble P
  - Organic
  - Inorganic
- Total K

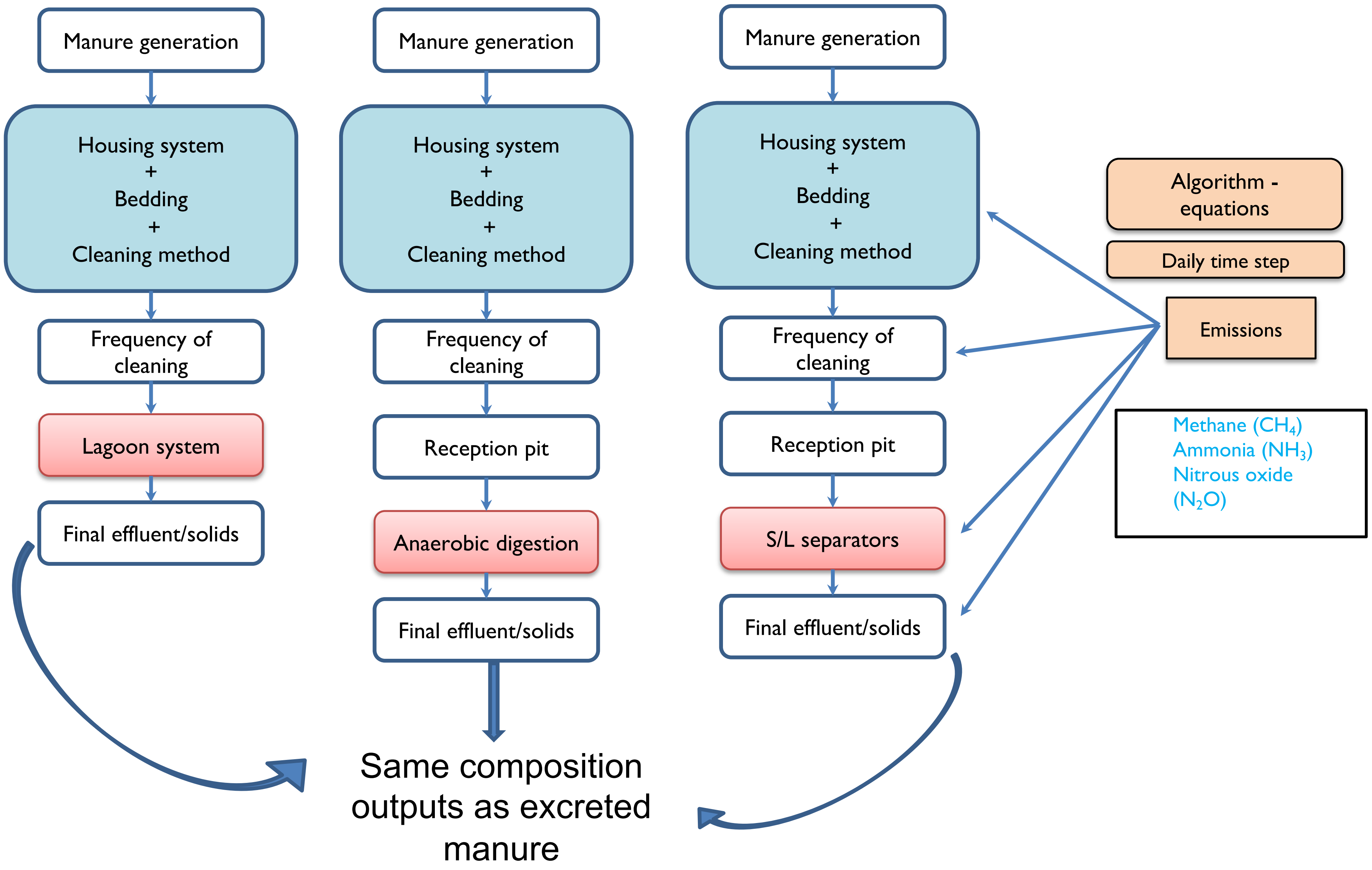
Outline

Outline:

- Manure Generation
- Cleaning & collection
- Processing/Treatment
- Storage
- Application



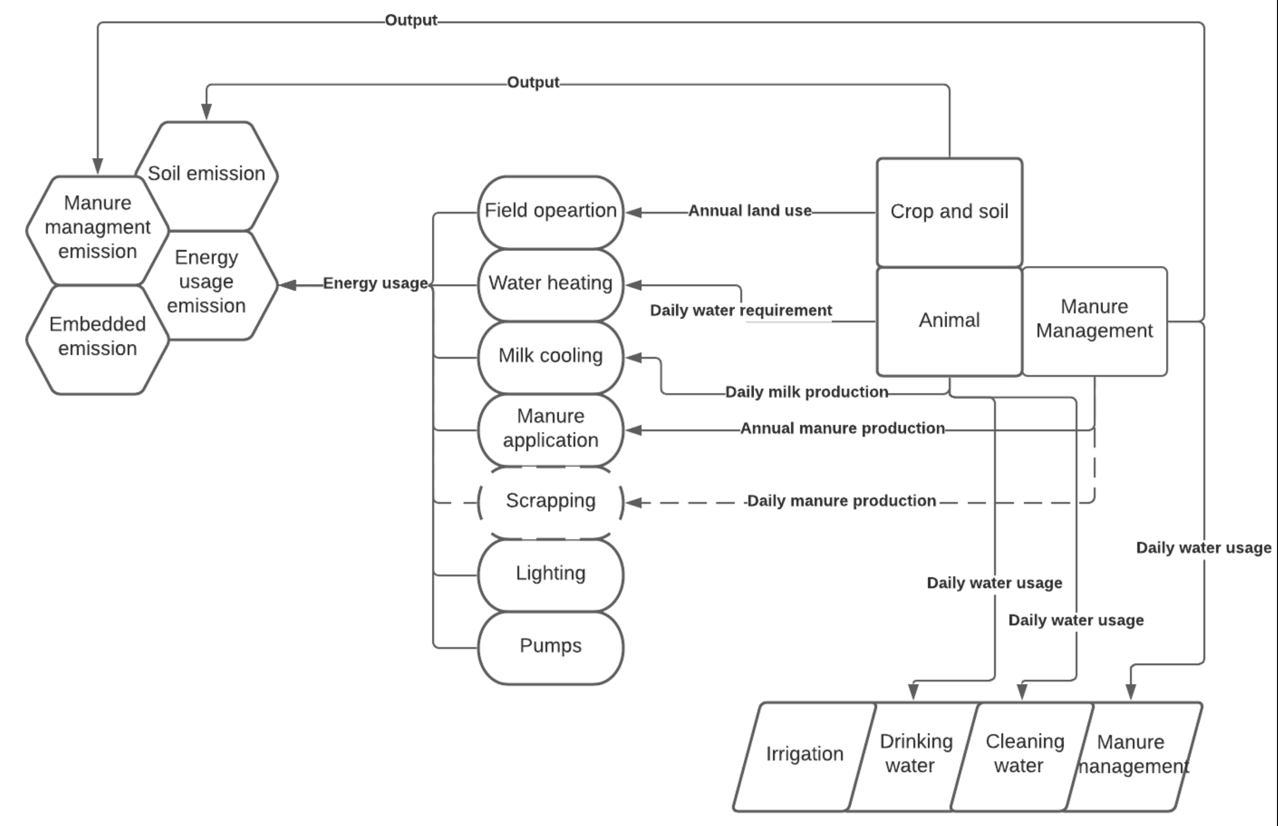
Processes

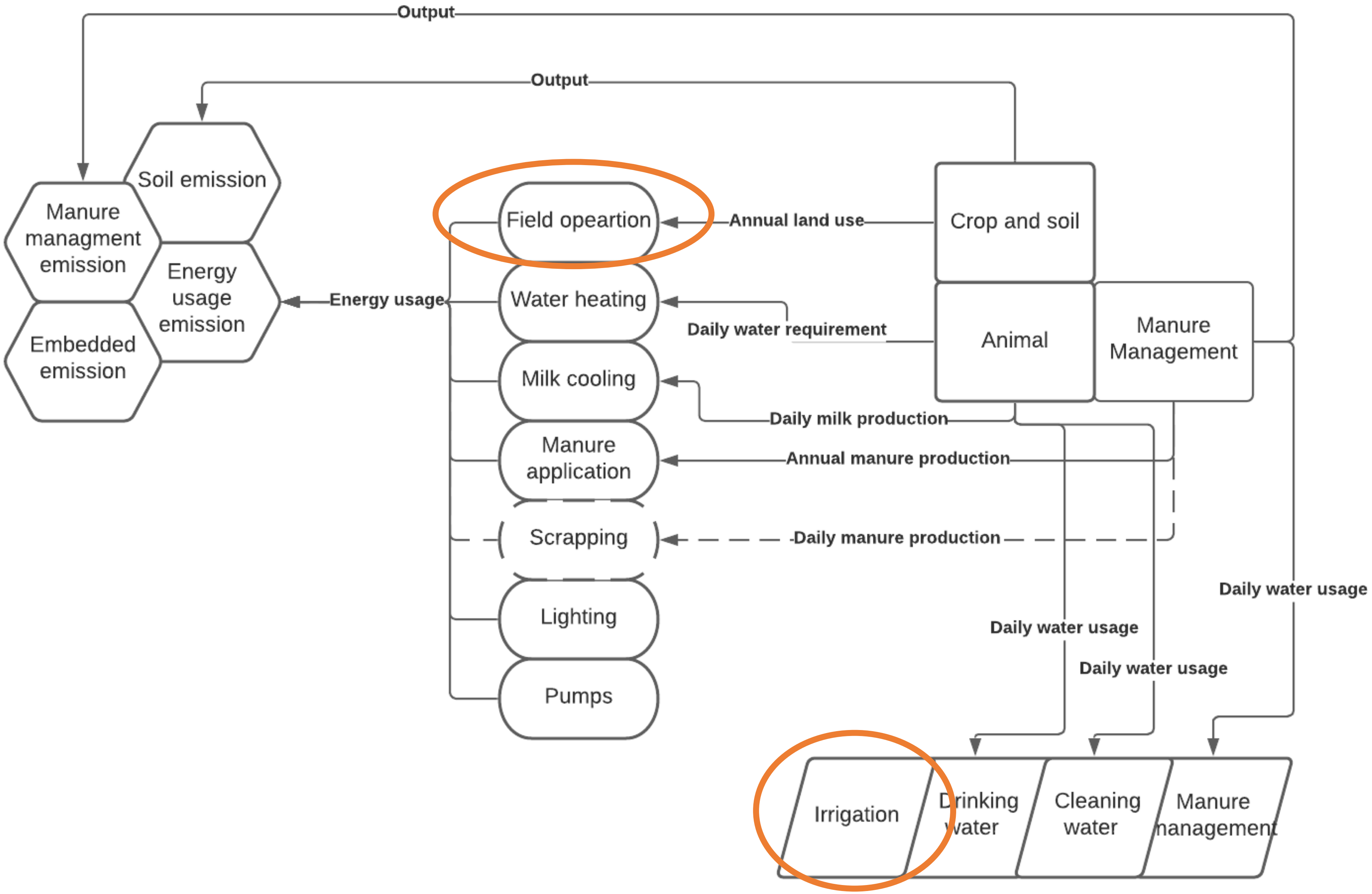

Manure generation
Housing system + Bedding + Cleaning method
Frequency of cleaning
Lagoon system
Final effluent/solids
Manure generation
Housing system + Bedding + Cleaning method
Frequency of cleaning
Reception pit
Anaerobic digestion
Final effluent/solids
Manure generation
Housing system + Bedding + Cleaning method
Frequency of cleaning
Reception pit
S/L separators
Final effluent/solids
Algorithm - equations
Daily time step
Emissions
Methane (CH_4)
Ammonia (NH_3)
Nitrous oxide (N_2O)
Same composition outputs as excreted manure

Field Energy Use

System Balance

Summarizing the biophysical module into useful economic, energy, and GHG reports.




Output
Output
Soil emission
Manure managment emission
Energy usage emission
Embedded emission
Energy usage
Field opeartion
Water heating
Milk cooling
Manure application
Scrapping
Lighting
Pumps
Annual land use
Daily water requirement
Daily milk production
Annual manure production
Daily manure production
Crop and soil
Animal
Manure Management
Daily water usage
Daily water usage
Daily water usage
Irrigation
Drinking water
Cleaning water
Manure management

Field Operation Energy Use – Keep it Simple

Fertilization, Tillage, Planting & Harvest

- Approach:
  - Land area fuel use factors
  - Small selection of equipment options
- Based on EPA MOVES2014 model
  - https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves
- Diesel Emissions factors:
  - Based on UK Department of Business, Energy and Industrial Strategy (~9.5 kg CO_2-eq/gal diesel)
  - Open to use of other factors

MOVES3: Latest Version of Motor Vehicle Emission Simulator

EPA's MOtor Vehicle Emission Simulator (MOVES) is a state-of-the-science emission modeling system that estimates emissions for mobile sources at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics.

Field operation:

$$\mathbf{F} = \sum_{i}^{n} (\mathbf{Fertilization} + \mathbf{Tillage} + \mathbf{Planting} + \mathbf{Harvesting}) \times \mathbf{Land}_i \qquad \text{SB.1. E.1}$$

Field Operation Energy Use – Keep it Simple

Manure Application

Approach:

- Sum energy costs of pump, agitator, hauling
- Currently no irrigation manure application represented
- Degree of incorporation determined by % on surface and depth of application

Manure application:

pump

Variable	Description	Unit
P_i	Power of pump *i*	kW
V	Volume of hauling tank	L
f	Volumetric flowrate of pump *i*	L/h

Agitator

Variable	Description	Unit
P_i	Power of agitator *i*	kW
h	Working hours of pump *i*	L

Manure hauling

Variable	Description	Unit
P	Diesel usage rate for selected hauling method	L/h
D_i	Hauling distance for trip *i*	km
v	Velocity of the hauling vehicle	km/h

Manure application:

Pump:

$$\mathbf{PP} = \sum_{i}^{n} \mathbf{P}_i \times \frac{\boldsymbol{V}}{\boldsymbol{f}_i} \qquad \text{SB.1. F.1}$$

Agitator:

$$\mathbf{AA} = \sum_{i}^{n} \mathbf{P}_i \times \boldsymbol{h} \qquad \text{SB.1. F.2}$$

Hauling:

$$\mathbf{HH} = \sum_{i}^{n} \mathbf{P} \times \frac{\boldsymbol{D}_i}{\boldsymbol{V}} \qquad \text{SB.1. F.3}$$

Total energy:

$$\mathbf{E} = \mathbf{PP} + \mathbf{AA} + \mathbf{HH} \qquad \text{SB.1. F.4}$$

Field Operations: Irrigation

- Currently a user input for farm grown feeds
- Future work to estimate irrigation timing and needs

Thanks for listening!

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