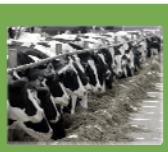
College of Agricultural & Life Sciences
UNIVERSITY OF WISCONSIN–MADISON

Assessment of Coordinated Anaerobic Digestion of Dairy Manure



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Livestock and Poultry Environmental Learning Center (LPELC)
Educational Webcast Series
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Overview

- **What is coordinated (centralized) management?**
- **Why consider cooperative digestion?**
- **Research questions**
- **Methodology**
- **Results and discussion**
- **Conclusions**

BioCycle
THE ORGANICS RECYCLING AUTHORITY.
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Breaking News: Wisconsin Clean Water and Renewable Energy RFP

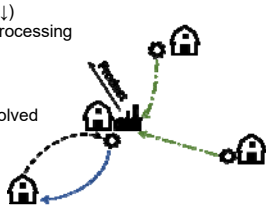
BioCycle News article, January 6th, 2017

What is centralized manure management?

Multiple independent producers collaborating on one or more aspects of manure processing/ conversion/end-use

Pros:
- Economies of scale (cost per cow ↓)
- Higher participation in advanced processing

Cons:
- Logistical challenges
- Process sensitive to all parties involved



Research questions

1) What parameters control profitability of centralized digesters?
2) Does centralization offer an economic advantage to AD systems?
3) Are there any general rules that could be deduced regarding centralization digestion ?

Study areas

Two regions

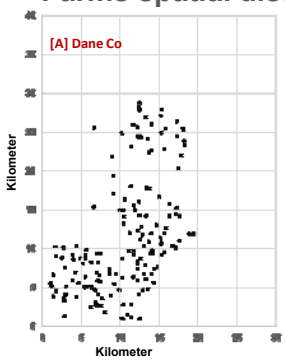
A. Upper Yahara, Dane County, WI
B. Kewaunee County, WI

Farm data

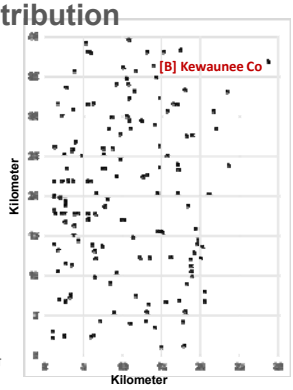
- Location (coordinates)
- Number of lactating cows
- Milk production

State of Wisconsin, USA

Farms spatial distribution

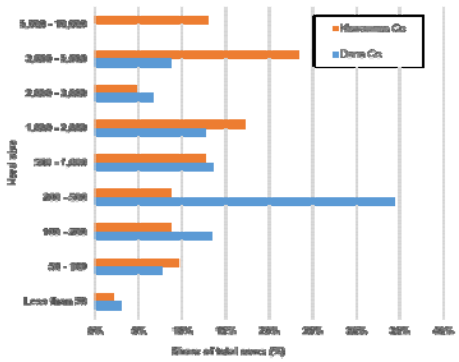


$N_{f(A)}$ = **156** farms, $N_{Cows\ (A)}$ = **38,851** cows

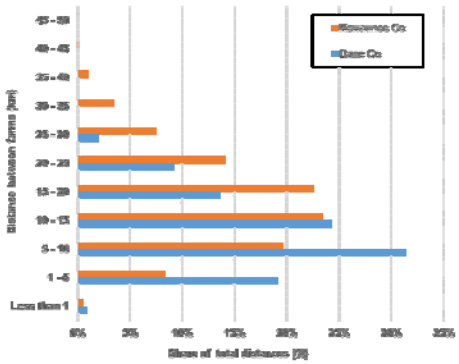


$N_{f(B)}$ = **151** farms, $N_{Cows\ (B)}$ = **46,557** cows

Farms size distribution



Farms distance distribution



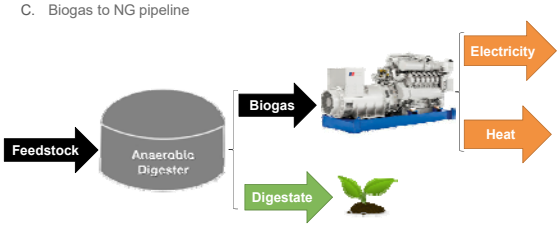
Process overview

Process description

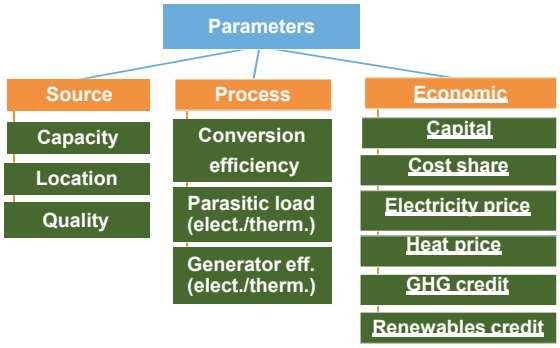
A. **Biogas-to-electricity & heat**

B. Biogas to LNG

C. Biogas to NG pipeline



Key process parameters



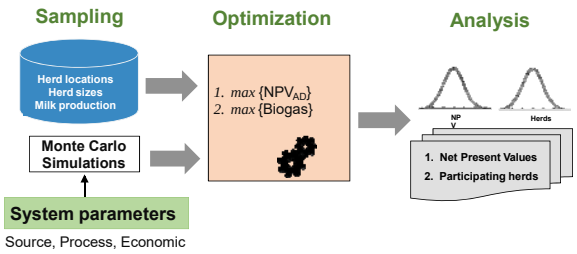
Optimization in livestock waste management

Approach

1. Use existing knowledge to generate values of the different parameters
2. Use mathematical optimization tools to determine optimal system in each case
3. Use statistical/graphical tools to analyze the optimal solutions

Optimization in livestock waste management

Approach



Sampled model parameters

Manure biomethane potential	**2.9 ~ 4.9**	cu.ft. $_{CH4}$ / lb. $_{VS}$
Digester efficiency	**77 ~ 94**	%
Generator efficiency (elect.)	**27 ~ 33**	%
Thermal recovery	**27 ~ 33**	%
Parasitic heating/electric load	**23 ~ 28**	%
Digester CAPEX	**550 ~ 677**	$/Cow (intercept = $355K)
Cost share	**27 ~ 33**	% of CAPEX
Electric energy sale price	**0.05 ~ 0.10**	$/kWh
GHG reduction credit	**1 ~ 10**	$/tCO2e
Renewable energy credits	**1 ~ 10**	$/REC (1 REC = 1 MWh)
Thermal energy price	**2 ~ 3**	$/MMBtu

Fixed model parameters

Discount factor	**8**	%
Project life	**20**	Years
Transportation cost (A)	**2.0**	$/ton
Transportation cost (B)	**0.30**	$/ton-mi
Feeding efficiency	**1.50**	lb. $_{FCM}$/lb. $_{DM}$
Dietary crude protein (%DM)	**18**	%
Dietary neutral detergent fiber (%DM)	**36**	%
Labor compensation	**25**	$/hr.
Full-time equivalent (FTE)	**1.0**	(-)

Problem size

Number of optimization runs

= study areas * objectives * parameters sampling events

= **2 * 2 * 1,000 = 4,000 optimization runs**

In each run, the optimization solver:

1. iterates over thousands of possible solutions
2. selects the ideal solution that maximizes the objective function (i.e., profitability, or technology adoption)

Results

1. **Regional differences**
   - NPV > 0 (profitability) probability
   - Parameter effect
   - NPV per cow
   - Breakdown of revenue and operating costs

2. **Sub-regional analysis (decision tool)**
   - Ranking criteria
   - Ranking diagrams

Results

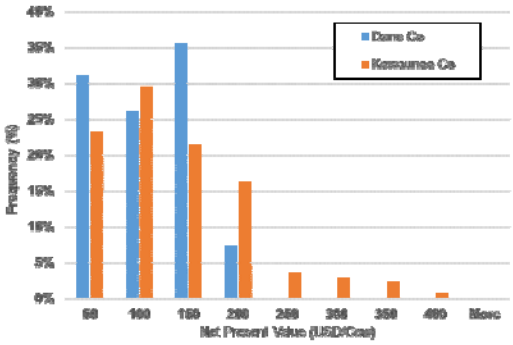
1. **Regional differences**

[A] Dane Co [B] Kewaunee Co

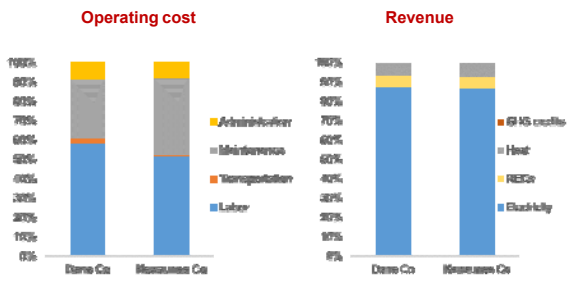
Optimization decisions for dairy manure digestion projects in

N = 1,000

Results



Results



Results

Sub-regional analysis (decision tool)

1. Ranking of farm *j* digester

ratio of the probability of a digester in farm *j* to the highest probability of digester construction on any farm (0 ~ 1)

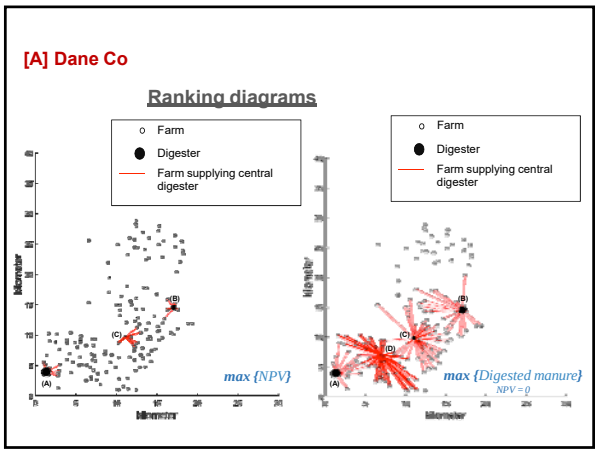
Farm ID	Probability	Ranking
1	20	14.0%
2	143	100.0%
3	2	1.4%
4	71	49.7%
5	12	8.4%

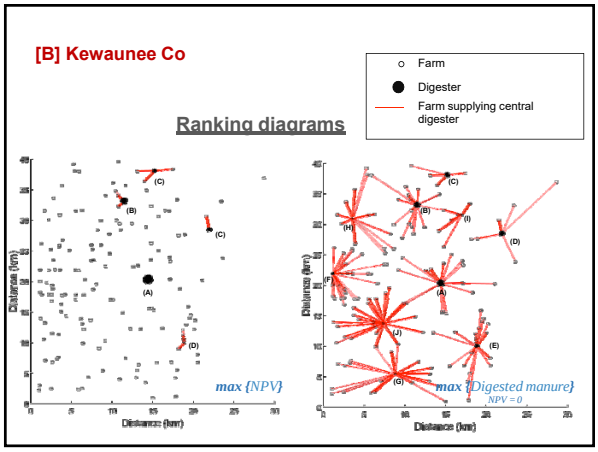
Results

Sub-regional analysis (decision tool)

2. Ranking of farm *j* hauling to digester *i*

ratio of the probability of farm *j* hauling manure to digester *i* to the highest probability of any farm participating in digester *i* (0 ~ 1)





Conclusions

- Profitability of dairy digesters for electricity is not there yet under current electricity markets.
- Profitability of cooperative dairy digesters are driven by herds size and spatial distribution.
- Both individual and cooperative digesters were sited at the largest herds.
- In both study areas, cooperative dairy digesters had the highest net present value (NPV) for digester projects.

Acknowledgments

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Questions?

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