Bioenergy Production as an Alternative Dairy Manure Management Strategy

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Overview

- Dairy Sector

  - ✓ Important component of agricultural economy.
  - ✓ Contribution to direct food supply.
  - ✓ Supplement of other co-products such as fiber, fertilizer, and energy.
  - ✓ income and employment contribution at the regional and national level.

New Mexico

- 315,183 number of dairy cows in 109 farms (2012, USDA).
- Ranks number one in dairy farm size with an average of 2,892 cows per farm in the United States.

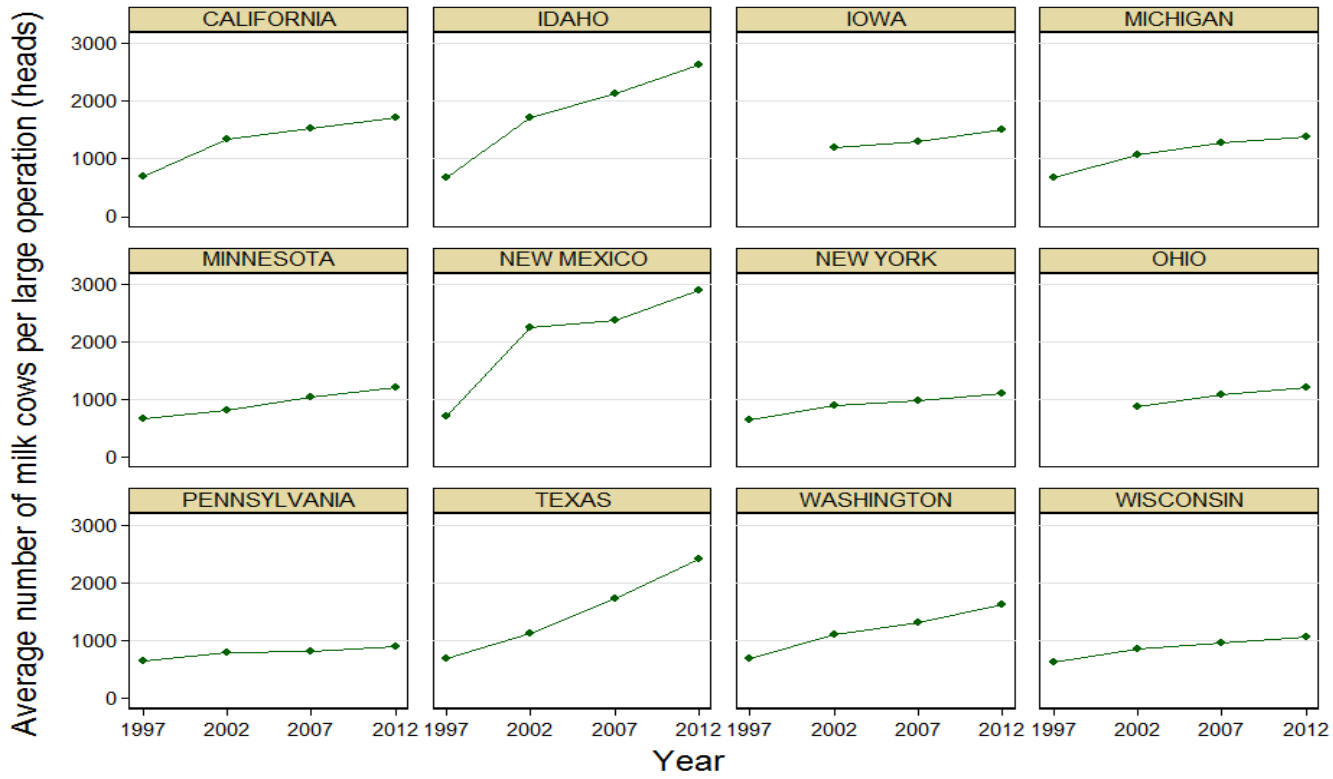
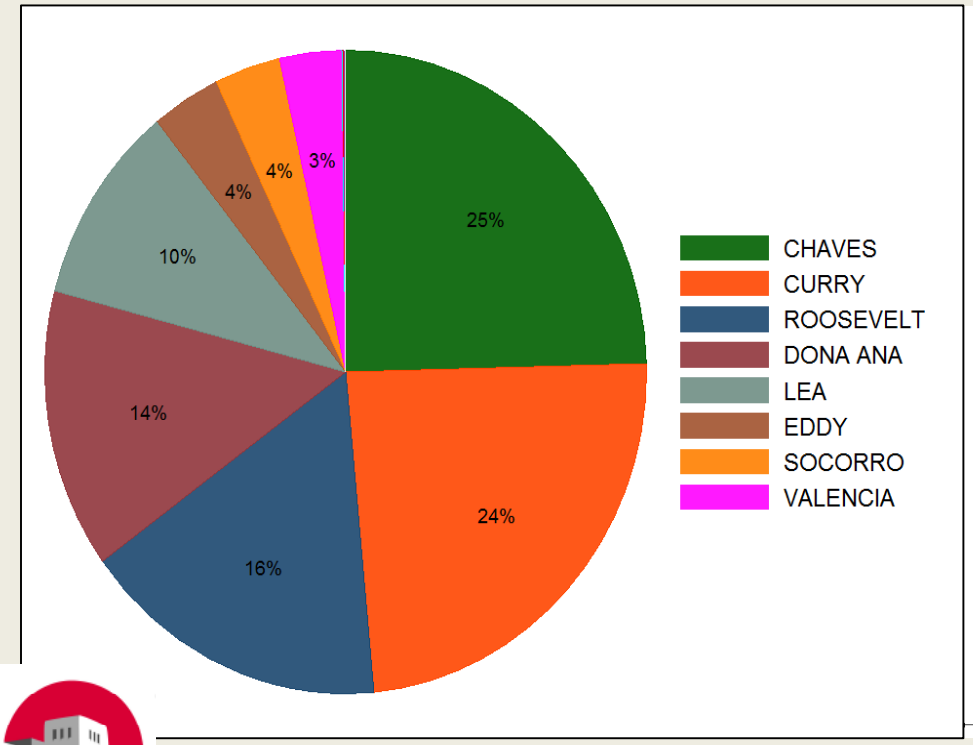
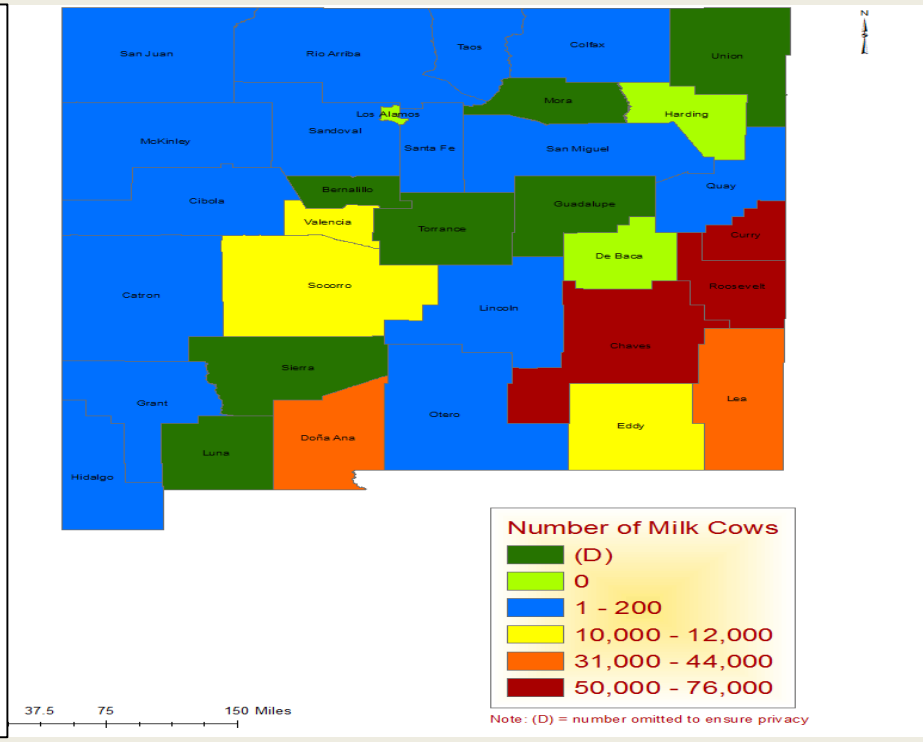


Figure 1: Average stocking density of milk cows in top twelve dairy states from 1997 to 2012

New Mexico

- 90% of milk cows are concentrated in the southeastern counties of the state.
- Economic contributions: 13.1% of the total agricultural outputs and 20.5% of the agricultural jobs.





Large Dairy Farms

- ❑ Structural changes with consolidation
  - ✓ Concentrated Animal Feeding Operations.
- ❑ Opportunities
  - ✓ Higher farm incomes due to economies of scale.
- ❑ Challenges
  - ✓ Manure Management.
  - ✓ Potential environmental problems:
    - ➢ Nutrient emissions, pathogens, sediments, and other trace elements (Can contaminate water sources).
    - ➢ air pollution.
    - ➢ GHGs emission.
  - ✓ Social cost to the surrounding communities.

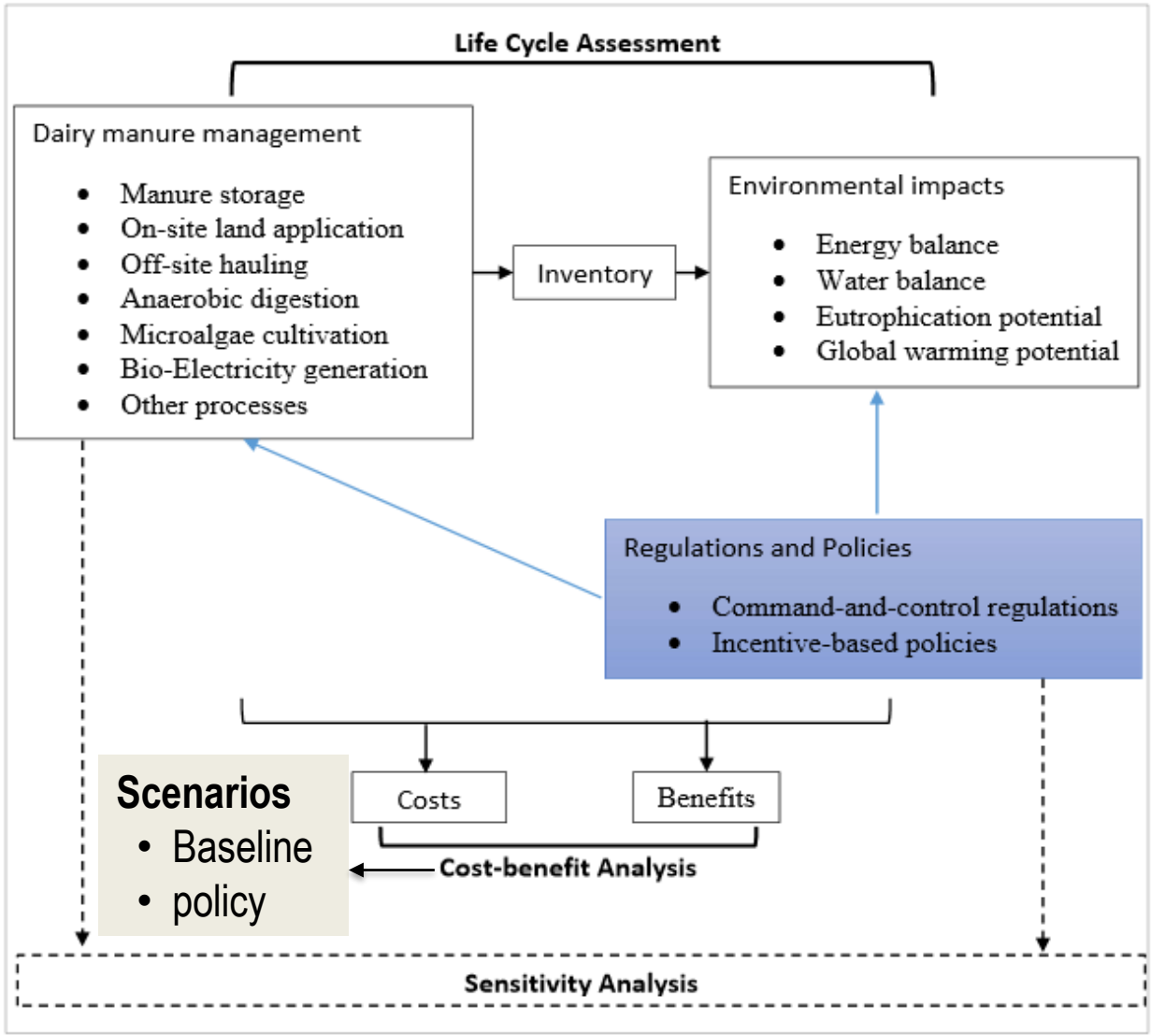
Research Objective

- Comparative environmental and economic assessment of alternative dairy manure management:
  - ✓ Case I: Direct Land Application (DLA).
  - ✓ Case 2: Anaerobic Digestion coupled with land application (AD).
  - ✓ Case 3: Anaerobic digestion coupled with microalgae production (ADMC).

Motivation

- Major Challenges
  - ✓ Manure management without affecting the environment is the dairy sector problem.
  - ✓ Reducing reliance on fossil fuels is important in the context of changing climate and energy security.
- Potential Solution
  - ✓ Integration of dairy manure management and bioenergy production (via anaerobic digestion and/or anaerobic digestion coupled with microalgae production)?
    - Nutrients are the major inputs, including the sunlight, water, and CO2 in the microalga biomass production.

Research Approach

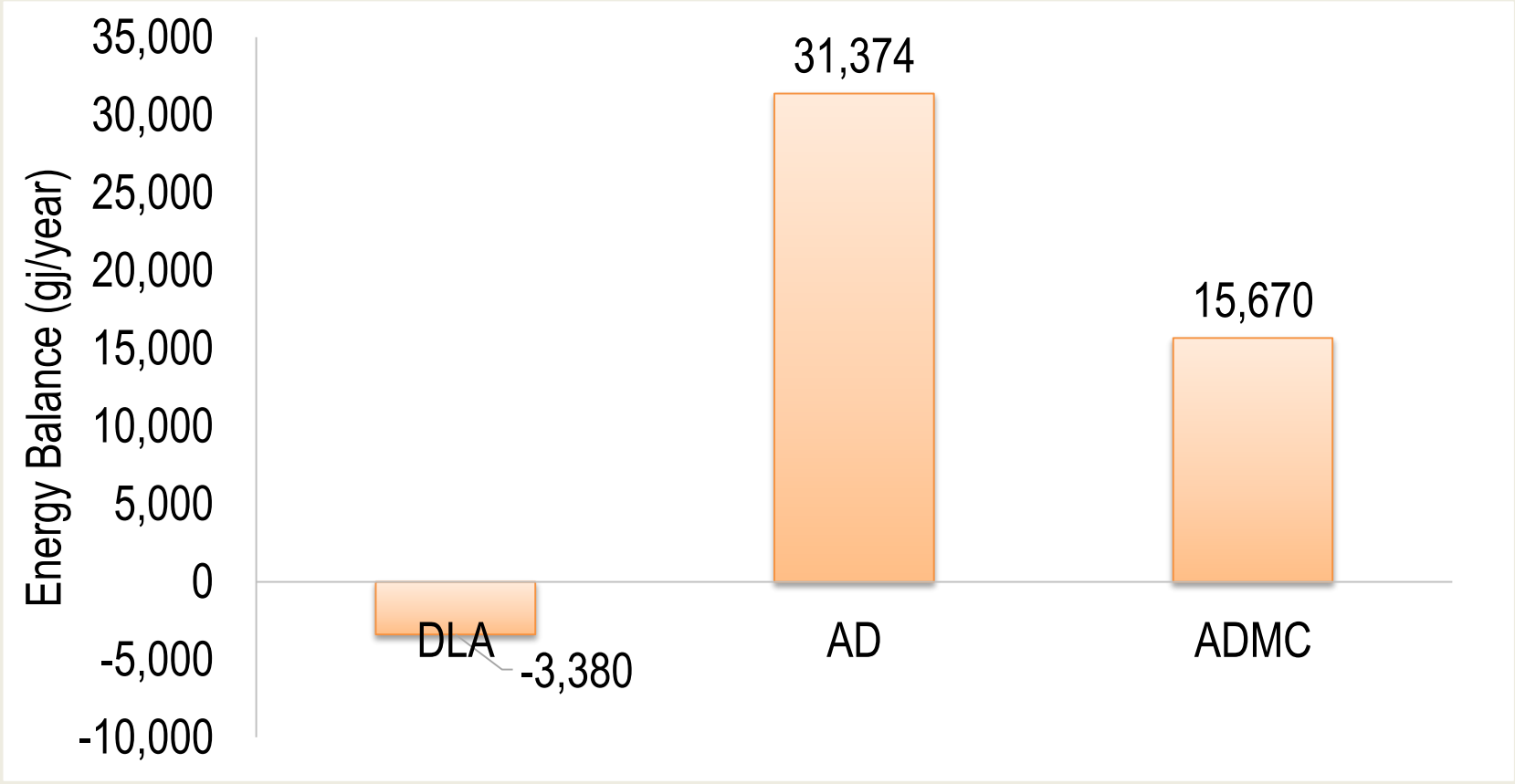


Data and Assumptions

- ✓ Typical dairy farm in New Mexico: 2,893 cows.
- ✓ Input-output data for both LCA and CBA were adapted from various peer reviewed literature, and other publicly available data (e.g. Zhang et al. 2013; NMSU ag center; USDA; IPCC; EPA etc.).
- ✓ Manure is applied to the agricultural land following the crop specific agronomic nitrogen application rate.
- ✓ Major crops in New Mexico: alfalfa, corn silage, and wheat.
- ✓ Excess manure is hauled off-farm.
- ✓ Microalgae is produced throughout the year.

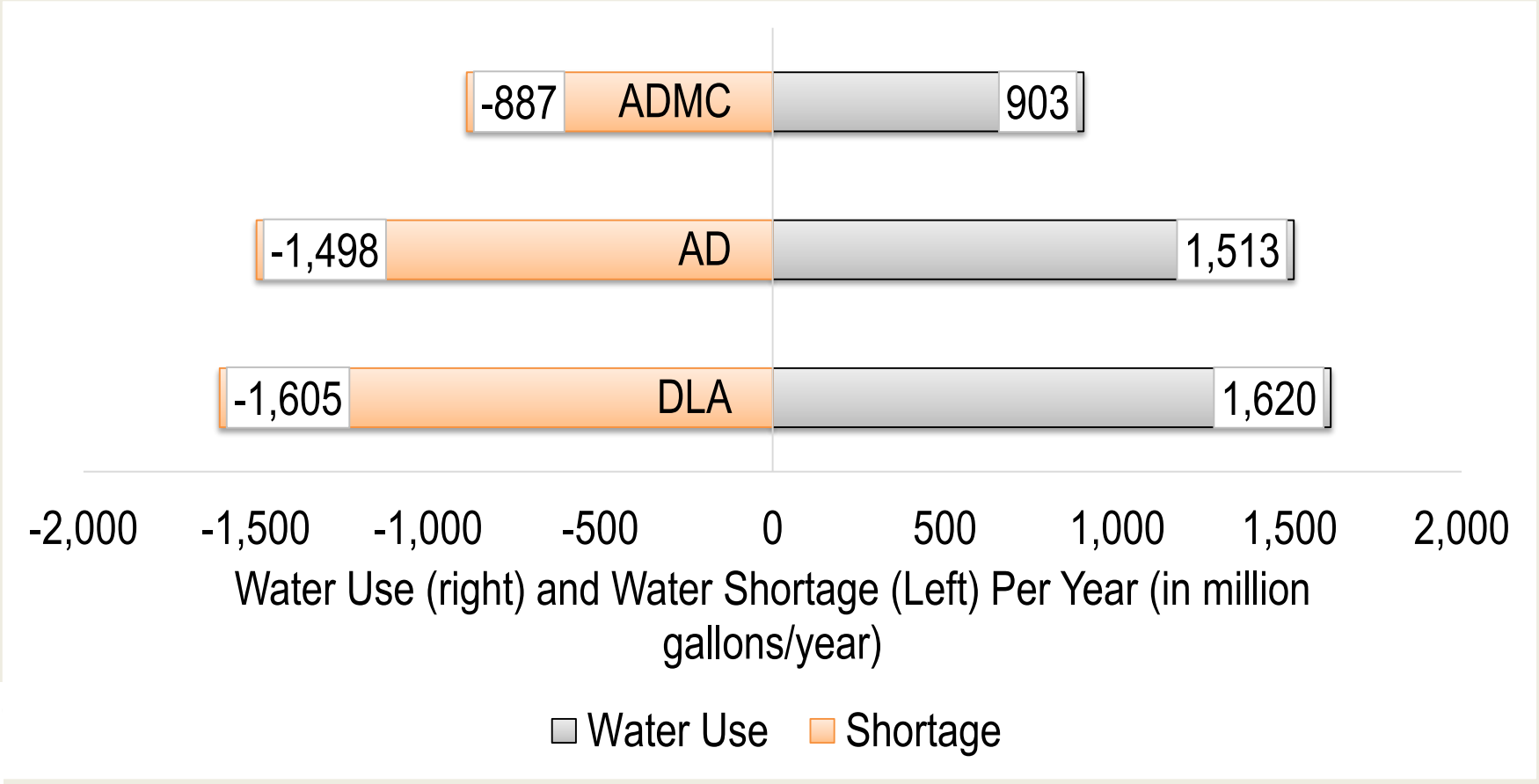
LCA Results

- Energy Balance:
  - ✓ Energy input minus energy output.



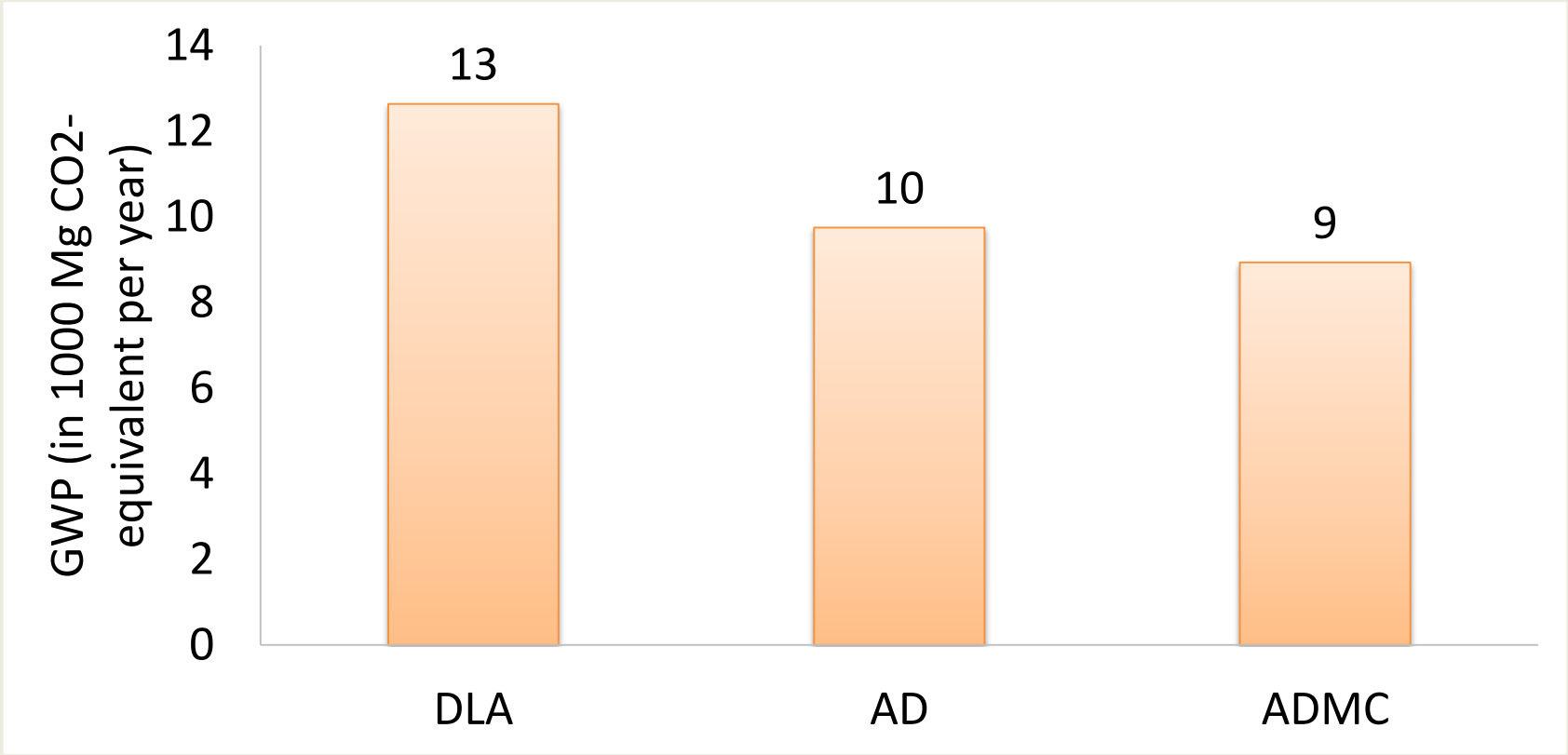
LCA Results…

- Water Balance:
  - ✓ Dairy wastewater minus case specific water requirement.



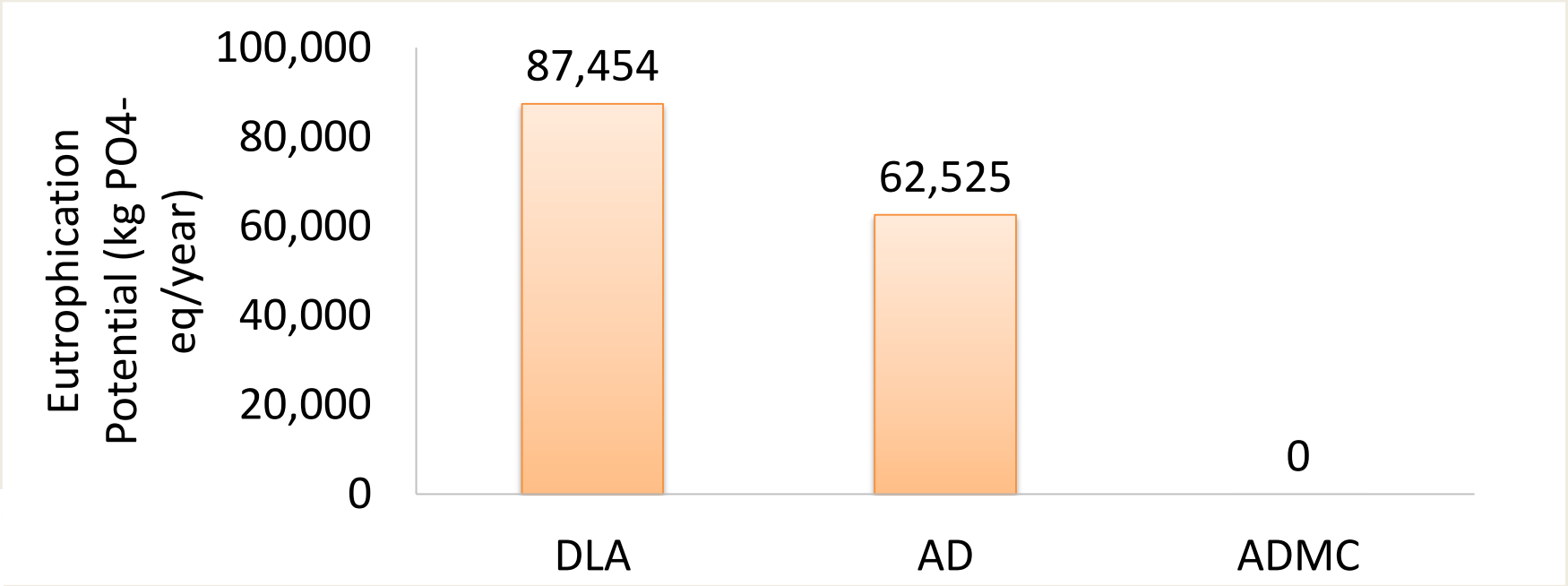
LCA Results…

- Global Warming Potential:
  - ✓ Total emissions of carbon dioxide, methane and nitrous oxide per functional unit (Zhang et at. 2013).



LCA Results…

- Eutrophication Potential:
  - ✓ Emissions of nutrients and other chemicals per FU
    - ➢ Nitrogen monoxide, nitrogen oxides, ammonium, nitrogen, phosphorus, (Zhang et al., 2013).
  - ✓ No EUT potential in ADMC as it recycles manure throughout the year.



Cost Benefit Analysis (CBA)

- CBA uses net present values to assess relative economic favorability of each case using the following equation:

$$\sum_{t=1}^{20}(Total\ Revenue - Total\ Cost)(Discount\ Rate).$$

- T=20 year cycle of each case, 5% discount rate.

- CBA Scenario:
  - ✓ Baseline
  - ✓ Policy
  - ✓ Sensitivity Analysis

CBA Results (Net Present value in million $)

Scenario	DLA	AD	ADMC
Baseline	-146.70	26.38	-5.12
Policy			
Current policy simulation	-146.70	27.82	-3.68
Prospective Policy simulation			
Carbon Credits	-146.70	27.04	-4.23
Nutrient credits	-146.70	33.95	71.79
Combined nutrient and carbon credits	-146.70	34.60	72.69

CBA Results (Net Present value in million $)

Scenarios	DLA	AD	ADMC
Sensitivity analysis			
Cropland availability	44.92	26.38	-5.12
Rangeland availability	21.29	26.38	-5.12
Current policy simulation (+25%)	-146.70	30.08	-3.32
Current policy simulation (-25%)	-146.70	27.46	-4.26
Prospective Policies simulation (+/-25%)			
Carbon Credits (+25%)	-146.70	27.20	-4.00
Carbon Credits (-25%)	-146.70	26.87	-4.45
Nutrient credits (+25%)	-146.70	35.84	91.02
Nutrient credits (-25%)	-146.70	32.06	52.57
Combined nutrient and carbon credits (+25)	-146.70	36.65	92.14
Combined nutrient and carbon credits (+25)	-146.70	32.54	53.23

Discussion

- AD demonstrates consistency in economic favorability across all scenarios.
- ADMC is consistent in environmental favorability.
- ADMC is also economically favorable provided the environmental credit trading market.
- Incentive-based public policies are appropriate for motivating dairy farmers to co-produce renewable energy using the anaerobic digestion of manure coupled with microalgae:
  - ✓ Reduce compliance costs of large dairies.
  - ✓ Contribute to reduce fossil fuel dependency.
- Renewable energy production co-exist with food production without a competition in AD and ADMC case.

Conclusion

- Dairy farms consolidation leads higher farms incomes due to economies of scale.
- Dairy farms can generate additional income by integrating anaerobic digestion of dairy manure management with manure land application.
- ADMC helps minimize external costs of the dairy farmer.
- Environmental credit trading market can create environmental and economic incentives to dairy farmers to use manure for bioenergy production.

Thank You

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Questions?