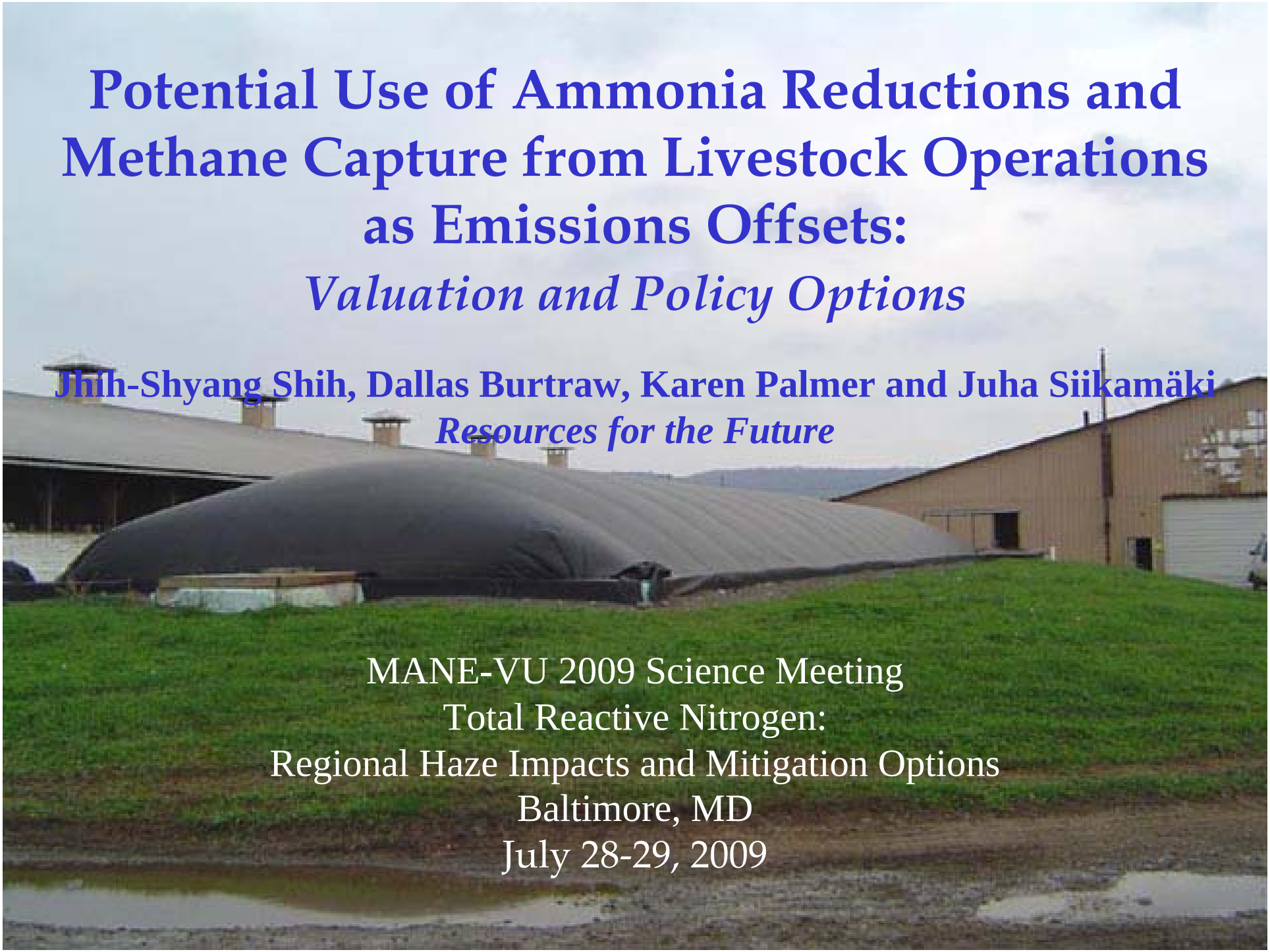
Potential Use of Ammonia Reductions and Methane Capture from Livestock Operations as Emissions Offsets:

Valuation and Policy Options

Jhih-Shyang Shih, Dallas Burtraw, Karen Palmer and Juha Siikamäki

Resources for the Future



MANE-VU 2009 Science Meeting
Total Reactive Nitrogen:
Regional Haze Impacts and Mitigation Options
Baltimore, MD
July 28-29, 2009

Motivation

- Ammonia contributes directly to formation of secondary particulates
- Methane is a potent greenhouse gas
- Agriculture is major source
- Demands for environmental improvement will put increasing pressure on agriculture
- Will future policy involve regulatory constraints or flexible incentives???

Agriculture will either be
"at the table" or "on the table"

RESOURCES FOR THE FUTURE

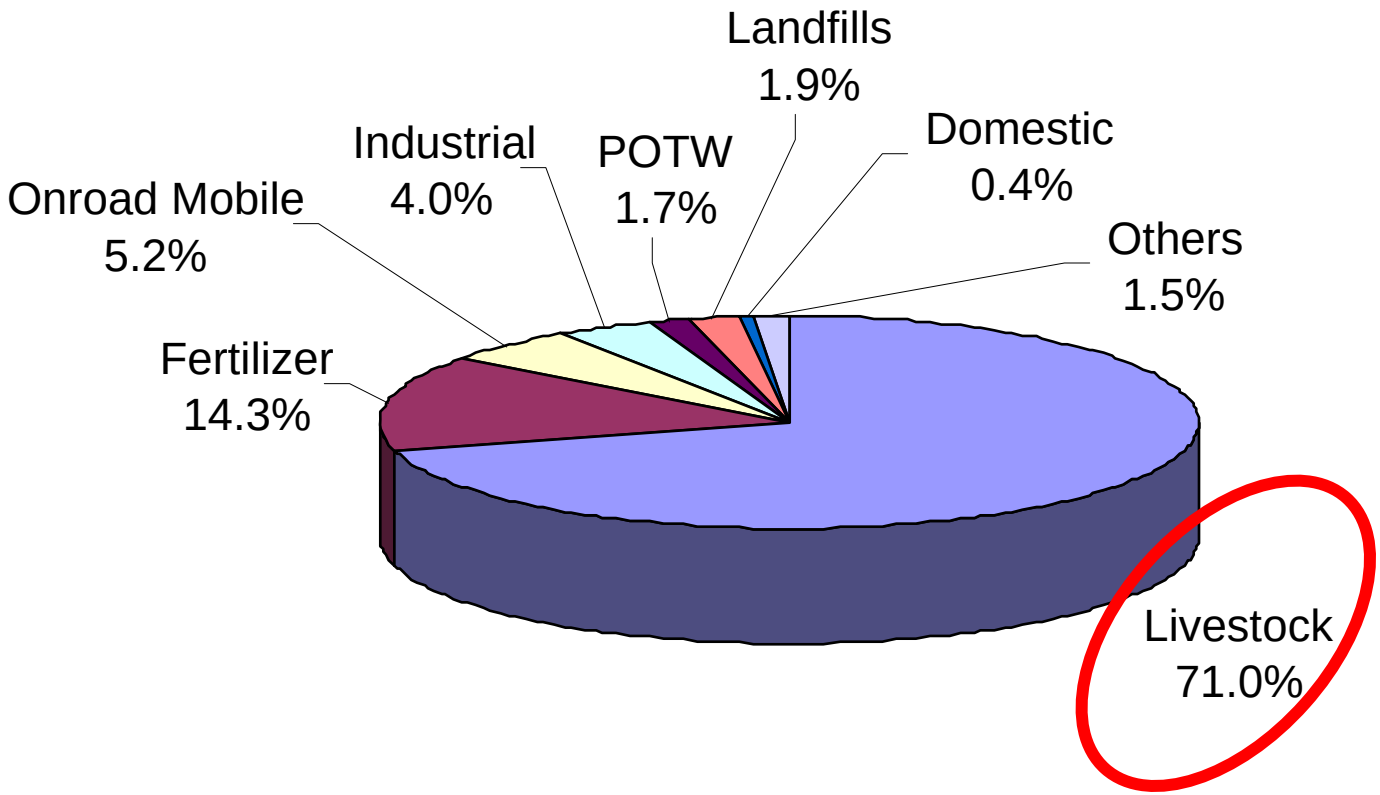
Objectives

- To develop an integrated, farm-level process model to examine the full range of benefits and costs of control technologies for air emissions of ammonia and methane from dairy operations.

- To explore the potential of market-based policies to encourage adoption of methane and ammonia control technologies:
  - Particulate matter offset credits for *ammonia* control
  - Greenhouse gas offset credits for *methane* control
  - Net metering policy for the *sale of electricity* generated from methane gas

RESOURCES FOR THE FUTURE

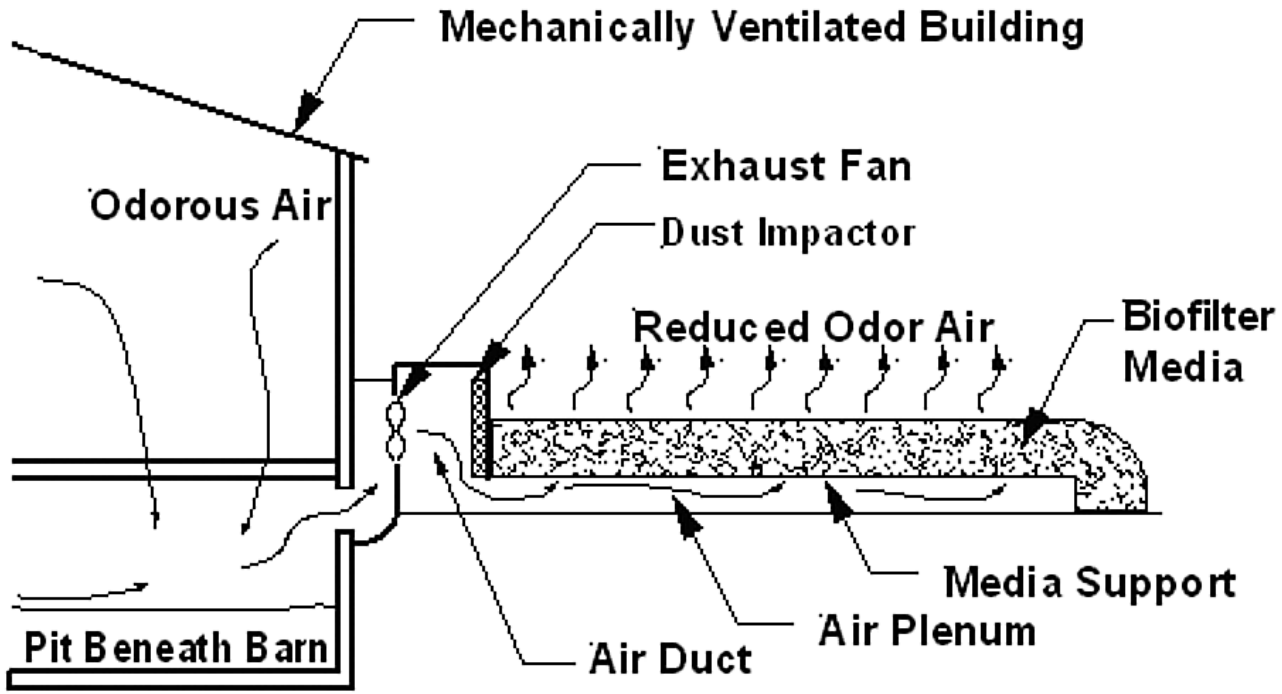
U.S. Ammonia Emissions by Source



Source: Roe et al., 2004

RESOURCES FOR THE FUTURE

Typical Open-Bed Biofilter



Source: Nicolai and Schmidt, South Dakota FS 925-C

Biofilter media is a layer of organic material, typically compost and wood chips, that supports a population of microbes.

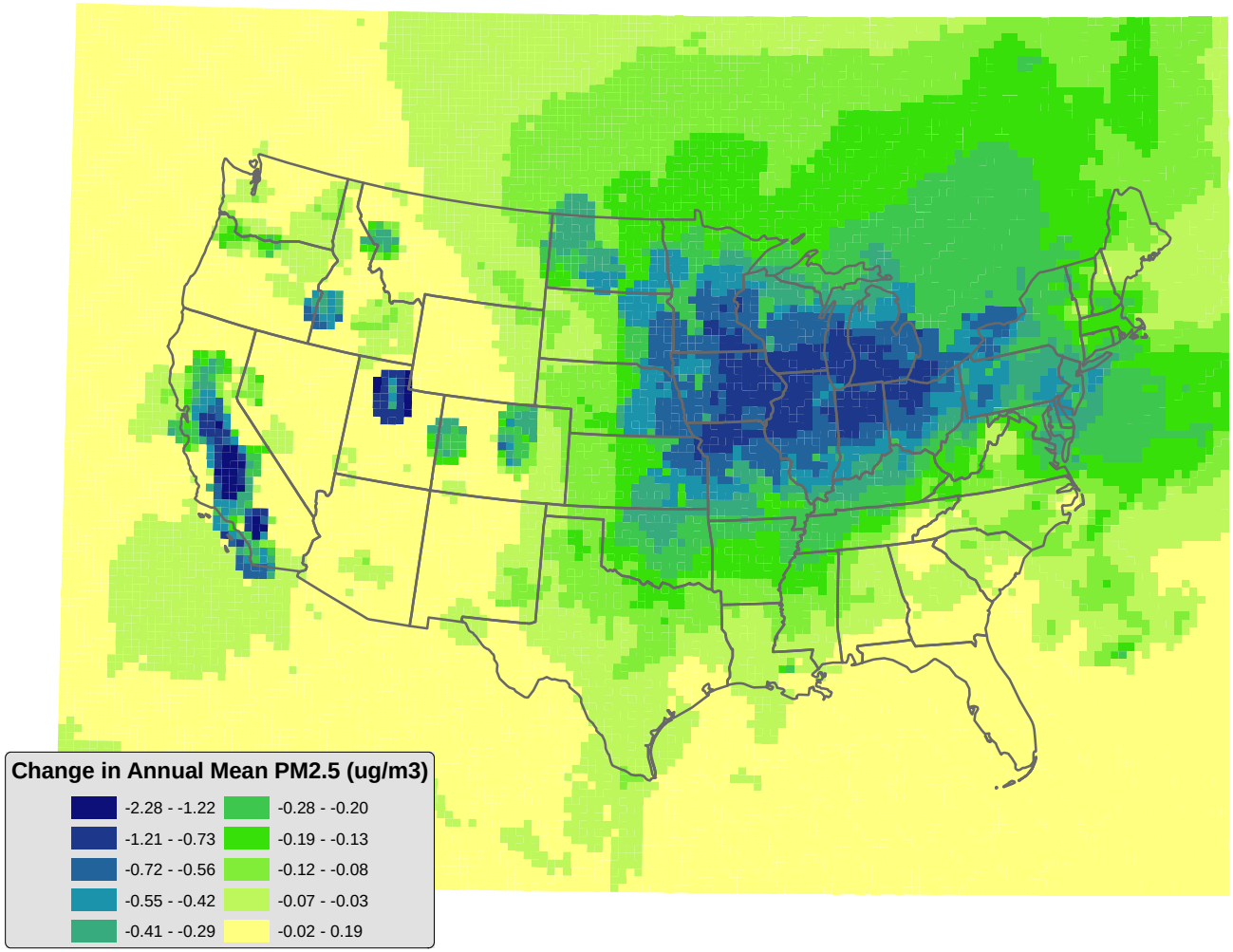
RESOURCES FOR THE FUTURE

Policy Context Relevant to Biofilters

- In practice, biofilters used primarily odor control, but also removes ~65% of ammonia.
- Ammonia conversion factors for ammonia
  - to ammonium nitrate: 4.706
  - to ammonium sulfate: 3.882
- New PM2.5 standards for 2020.
- Currently there is no accounting for benefits of avoided PM 2.5 resulting from control of ammonia in planning to meet standards or in Emission Reduction Credit markets.
- Pollutant formation is very dependent on local conditions, so considerations perhaps best situated to emissions reduction credit markets for PM10 or PM2.5 (Secondary PM2.5 account for ~50%-60% of PM10 by weight.)

RESOURCES FOR THE FUTURE

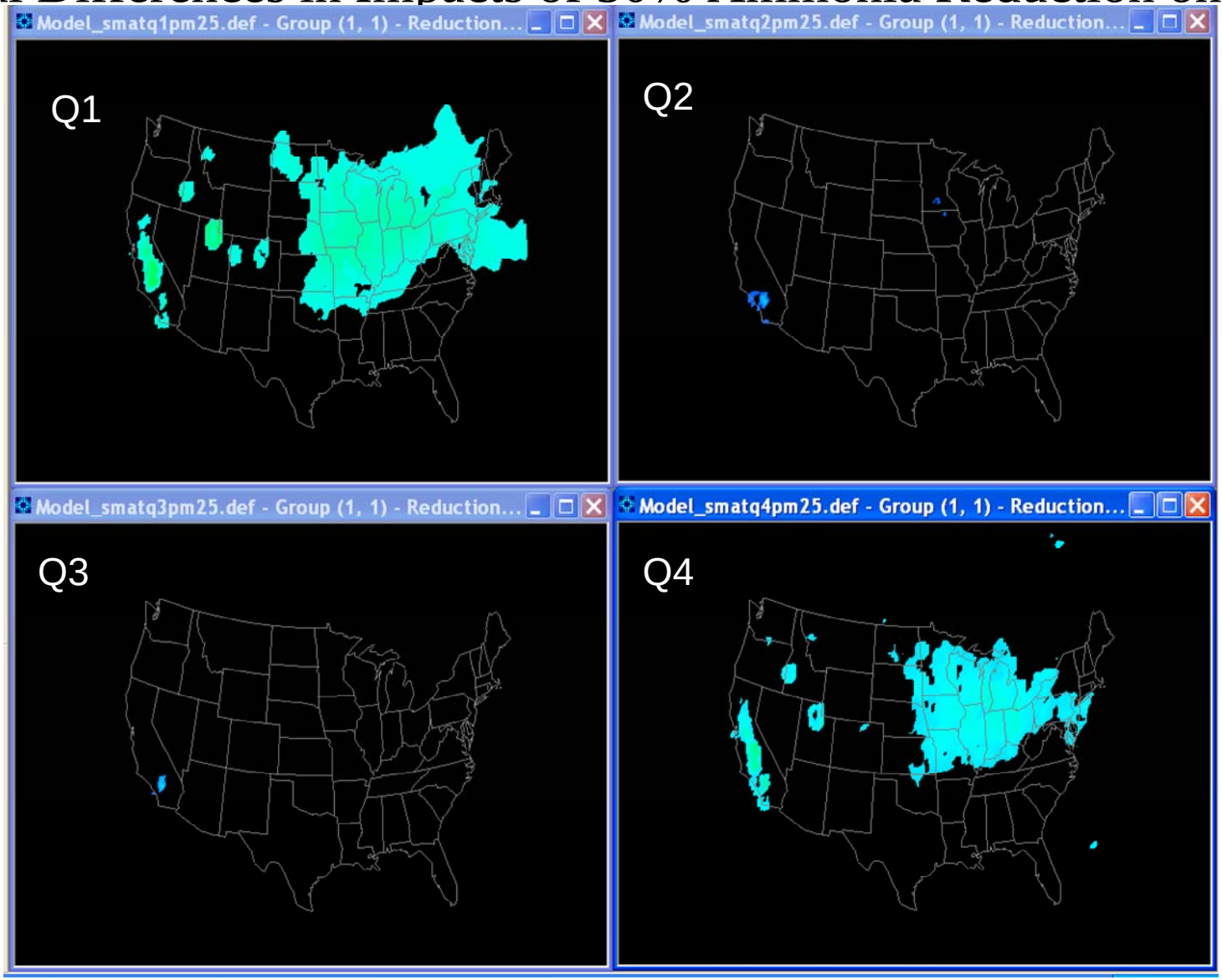
Impact on Annual Mean PM2.5 Concentrations of a 50 Percent Reduction in Agricultural Ammonia



RESOURCES FOR THE FUTURE

Personal Communication: Bryan Hubbell
hubbell.bryan@epa.gov

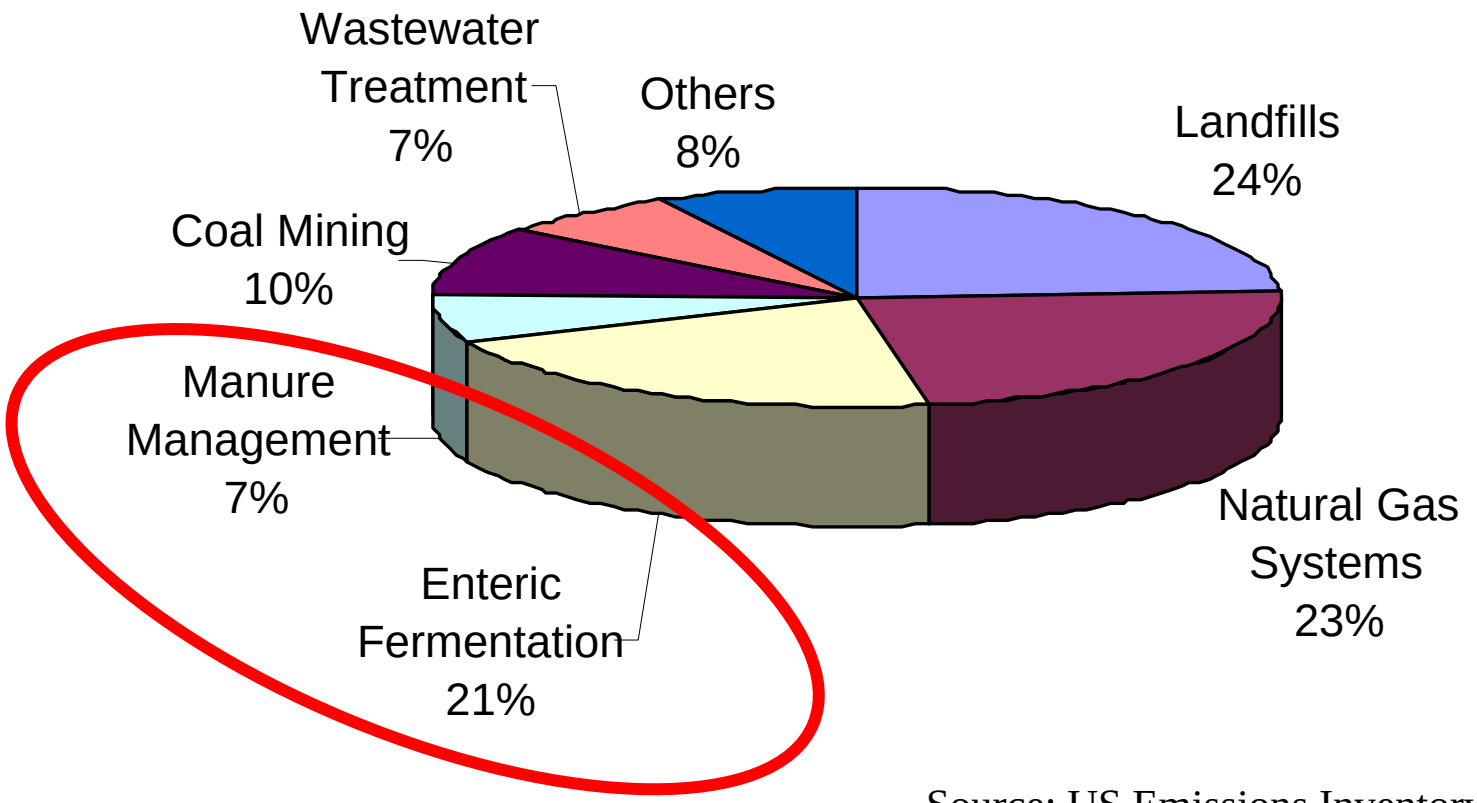
Seasonal Differences in Impacts of 50% Ammonia Reduction on PM2.5



RESOURCES FOR THE FUTURE

Personal Communication: Bryan Hubbell
hubbell.bryan@epa.gov

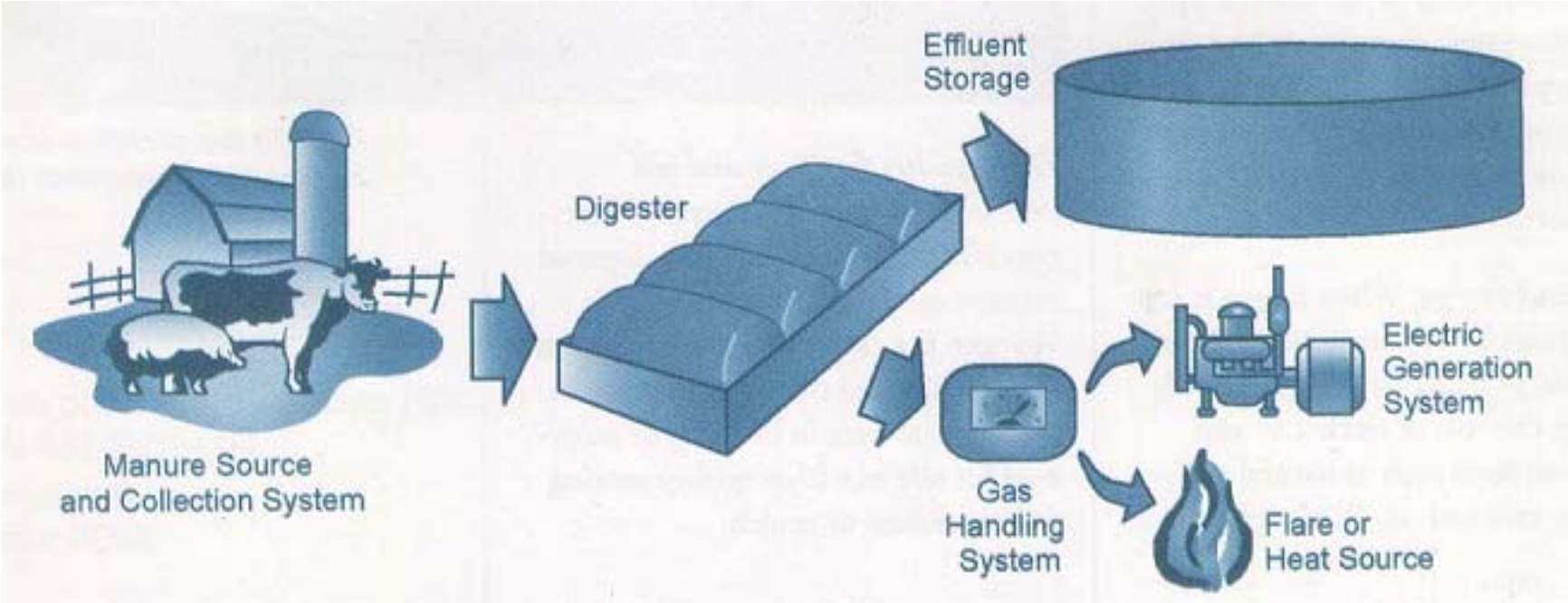
We Also Look at U.S. Methane Emissions



Source: US Emissions Inventory 2005

RESOURCES FOR THE FUTURE

Anaerobic Digestion Systems for Livestock Manures



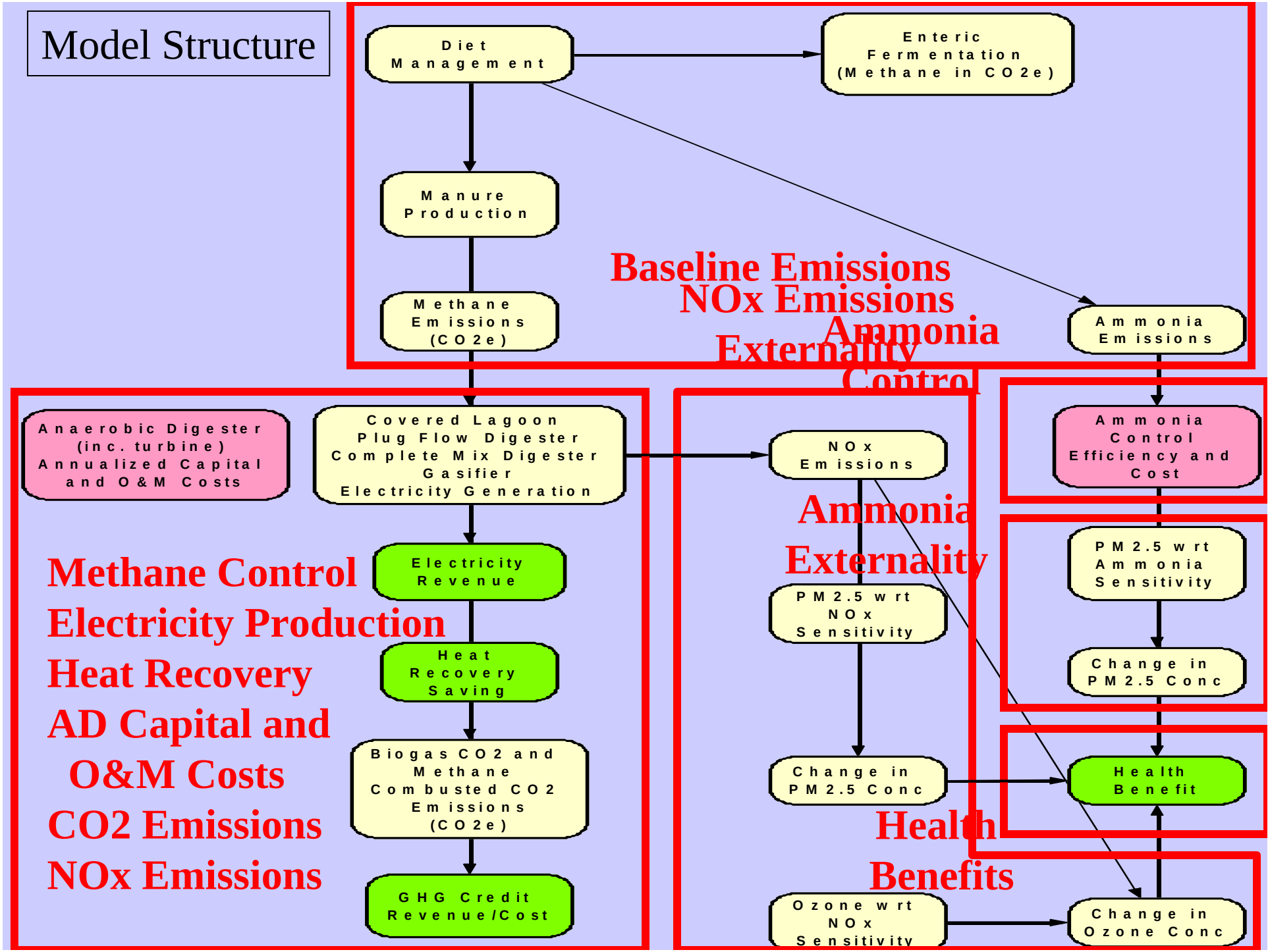
Source: EPA AgSTAR Program, 2007

Policies Relevant to Anaerobic Digester (AD)

- California's Global Warming Solutions Act of 2006 (AB 32) considers AD as a tier 2 GHG emission reduction measures in the 2007-2009 time period, with rulemaking to occur as soon as possible where applicable.

- RGGI considers AD as an eligible greenhouse gas offset project for manure storage and management. Specific model rule has been developed.

- European countries, for example Germany, have thousands of farm-based digesters and are producing significant quantities of biogas.


Model Structure
Diet Management
Enteric Fermentation (Methane in CO2e)
Manure Production
Methane Emissions (CO2e)
Ammonia Emissions
Baseline Emissions
NOx Emissions
Ammonia Externality
Control
Anaerobic Digester (inc. turbine) Annualized Capital and O&M Costs
Covered Lagoon
Plug Flow Digester
Complete Mix Digester
Gasifier
Electricity Generation
NOx Emissions
Ammonia Control Efficiency and Cost
Electricity Revenue
Heat Recovery Saving
Biogas CO2 and Methane Combusted CO2 Emissions (CO2e)
GHG Credit Revenue/Cost
PM 2.5 wrt Ammonia Sensitivity
Change in PM 2.5 Conc
PM 2.5 wrt NOx Sensitivity
Change in PM 2.5 Conc
Health Benefit
Ozone wrt NOx Sensitivity
Change in Ozone Conc
Methane Control
Electricity Production
Heat Recovery
AD Capital and O&M Costs
CO2 Emissions
NOx Emissions
Ammonia Externality
Health Benefits

Policy Analysis Scenarios

- Ammonia Control:
  - adopt biofilter
  - account for the social benefit of reduction in ammonia emissions
- Methane Control:
  - adopt anaerobic digester for methane control
  - consider electricity cost saving from own electricity consumption (no net metering for excess electricity generated)
  - account for GHG credits revenue
- Electricity Sale:
  - expanded net metering of electricity (excess electricity provided back to the electricity grid)

RESOURCES FOR THE FUTURE

Model Parameter Values

Ammonia emissions factor (lb/head/year)	18.5
Methane emissions factor (lb/head/year)	167
Manure production (lb/lb body wt/day)	0.08
Typical dairy cow body weight (lb)	1000
Manure solid percentage (%)	12.7
Biogas methane content (%)	60

Particulate (nitrate) formation efficient, with decay (%)	50
CO2 price ($/ton)	11
Digester life time (years)	20
Retail electricity price ($/kwh)	0.11
Net metering rate ($/kwh)	0.06

RESOURCES FOR THE FUTURE

Ammonia Control ($/year)

	Dairy size (cows)		
	400	500	1,000
Ammonia control			
Health benefits (PM)	12,030	15,040	30,070
Biofilter cost	120	150	300
Net benefits	*11,910*	*14,890*	*29,770*

RESOURCES FOR THE FUTURE

Ammonia Control ($/year)

	Dairy size (cows)		
	400	500	1,000
Ammonia control			
Health benefits (PM)	12,030	15,040	30,070
Biofilter cost	120	150	300
Net benefits	*11,910*	*14,890*	*29,770*

(Alternative cost-effectiveness approach: emission reduction credits values for PM10 in in 2007 CA's San Joaquin Valley range from $8,696/ton to $90,000/ton. Assuming efficient nitrate formation with 50% decay, 111 cows yield one ton ammonia converting to 2.35 tons nitrate. The ERC value at a 500 cow facility would be $39,171 to $405,000.)

RESOURCES FOR THE FUTURE

Methane Control ($/year)

	Dairy size (cows)		
	400	500	1,000
Methane control			
Electricity savings	21,910	27,380	54,770
Electricity sales			
GHG credit revenues	4,811	6,014	12,030
Health benefits (ozone)	-263	-328	-656
Digester cost	29,680	31,350	37,160
Net benefits	*-3,222*	*1,716*	*28,984*

RESOURCES FOR THE FUTURE

Electricity Sales ($/year)

	Dairy size (cows)		
	400	500	1,000
Methane control			
Electricity savings	21,910	27,380	54,770
Electricity sales	9,860	12,330	24,640
GHG credit revenues	4,811	6,014	12,030
Health benefits (ozone)	-263	-328	-656
Digester cost	29,680	31,350	37,160
Net benefits	*6,638*	*14,046*	*53,624*

RESOURCES FOR THE FUTURE

Summary ($/year)

	Dairy size (cows)		
	400	500	1,000
Ammonia control			
Health benefits (PM)	12,030	15,040	30,070
Biofilter cost	120	150	300
Net benefits	*11,910*	*14,890*	*29,770*
Methane control			
Electricity savings	21,910	27,380	54,770
Electricity sales	9,860	12,330	24,640
GHG credit revenues	4,811	6,014	12,030
Health benefits (ozone)	-263	-328	-656
Digester cost	29,680	31,350	37,160
Net benefits	*6,638*	*14,046*	*53,624*
Potential total net benefits from emission controls	**18,548**	**28,936**	**83,394**

*Ammonia control benefit could be over estimated due to air quality model limitations and when the regional PM concentration is not ammonia limited

RESOURCES FOR THE FUTURE

What Do We Need from Science & Economics to Develop New Policies?

- Improve emissions inventory
- Develop farm level source-receptor coefficients
  - Ammonia, NOx → PM
  - 3-D air quality modeling
  - Ammonia inventory data
- Better understanding of GHG implications of different manure and livestock management approaches
- Improved total cost estimates of biofilters & digesters in agricultural operations, including O&M, opportunity cost, and transaction costs
- Consider multi-farm digesters instead of a single-farm facility
  - Transportation costs and externality
  - Examine the siting of multi-farm facilities
- Impacts on water quality and odor.

RESOURCES FOR THE FUTURE

What Innovations in Policy Are Needed?

- Identification of standard practice baselines for control of pollutants on the farm to enable incentive payments for "additional" emissions reductions
- Inter-Pollutant trading for Emission Reduction Credits
  ammonia, NOx → PM2.5
- More flexible NOx policy in the context of methane control, accounting for ammonia and PM2.5 co-benefit of methane control
- Offset markets for greenhouse gases
- Unlimited *time-of-day* net metering for electricity from agricultural practices

Conclusion

- We develop and demonstrate an integrated process model of dairy operations.
- This model is able to explore market-based policies to provide farm operators with financial incentives to adopt technologies for the control of methane and ammonia emissions.
- Preliminary evidence suggests there are significant benefits from the development of policies to promote market-based approaches for emission reduction.

RESOURCES FOR THE FUTURE

Conclusion

- The magnitude of the benefit depends: the scale of the system, and technology adopted as well as on important model assumptions regarding ammonia-to-PM source–receptor coefficients.

- Large uncertainty, especially about the fate of the emissions, motivates further research.

Thank you!

Resources for the Future
Shih@RFF.org
Burtraw@RFF.org

Questions or Comments?