LINKING PROFITABILITY, RENEWABLE ENERGY, AND EXTERNALITIES:

A SPATIAL ECONOMETRIC ASSESMENT OF THE SUSTAINIBILITY OF OHIO DAIRIES

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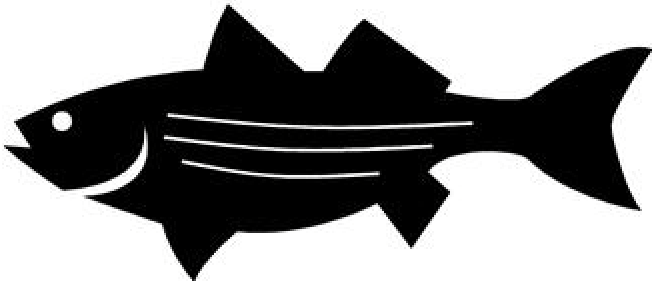
EXTERNALITIES

- Focus: Valuation of externalities & remedies…
- Motivation
- Data: Livestock operations across Ohio
- Modeling
- Results & implications
- The remedy (?)

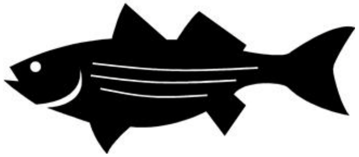
EXTERNALITIES



- **Between 1997 and 2002 *agriculture was responsible for about 22% of the 356 fish kills* in the state of Ohio and over 70% of these were due to livestock manure spills.**

- Between 2000 and 2003, **98** cases of animal waste (most dairy or swine) leakage documented in Ohio. Improper manure storage practices were responsible for 33% of these spills.

EXTERNALITIES

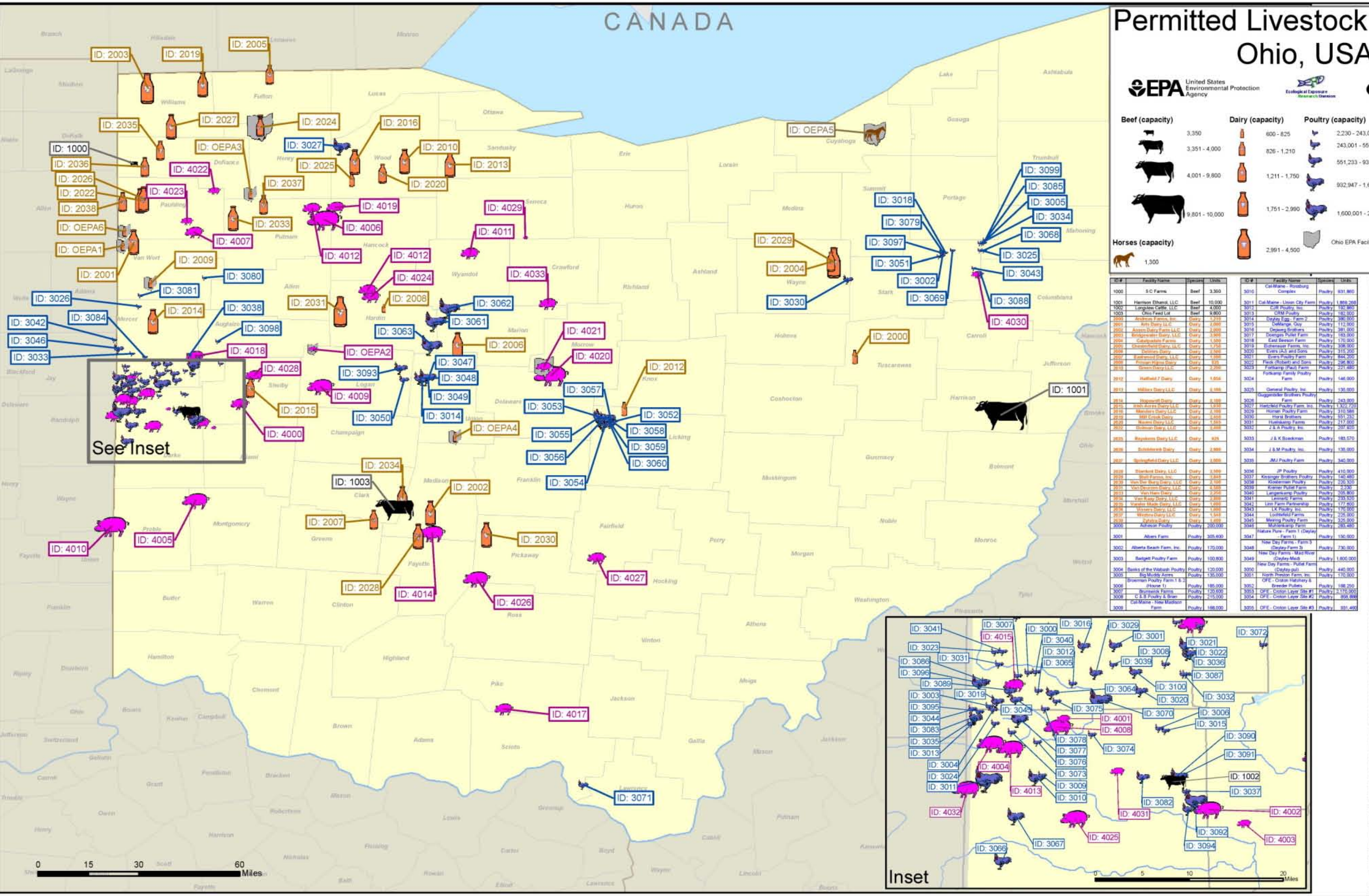


Runoff from farming operations contributes to eutrophication in near and far off water bodies…

?

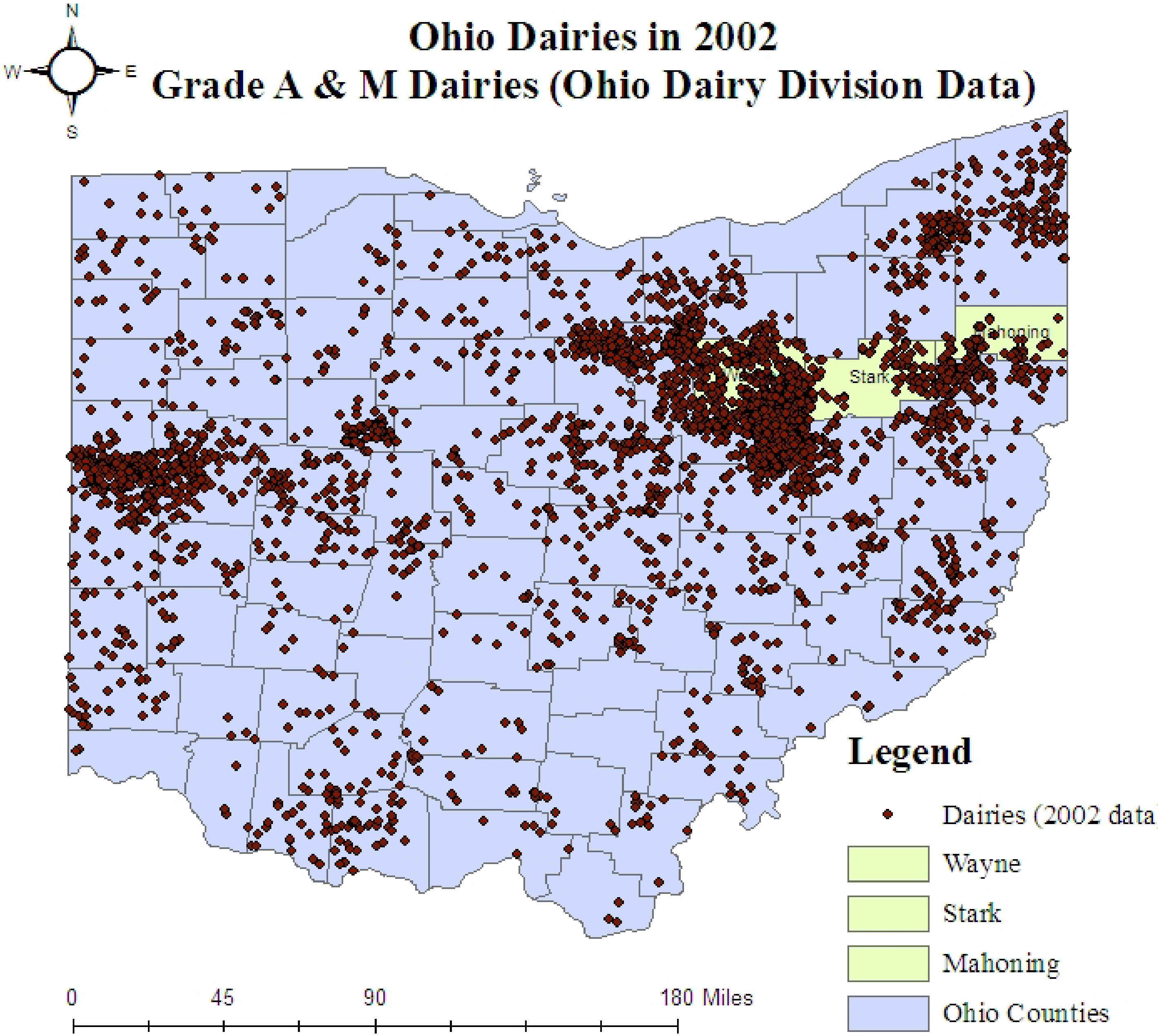
What is the actual cost of the environmental pollution stemming from livestock operations in dollar terms?

EXTERNALITIES

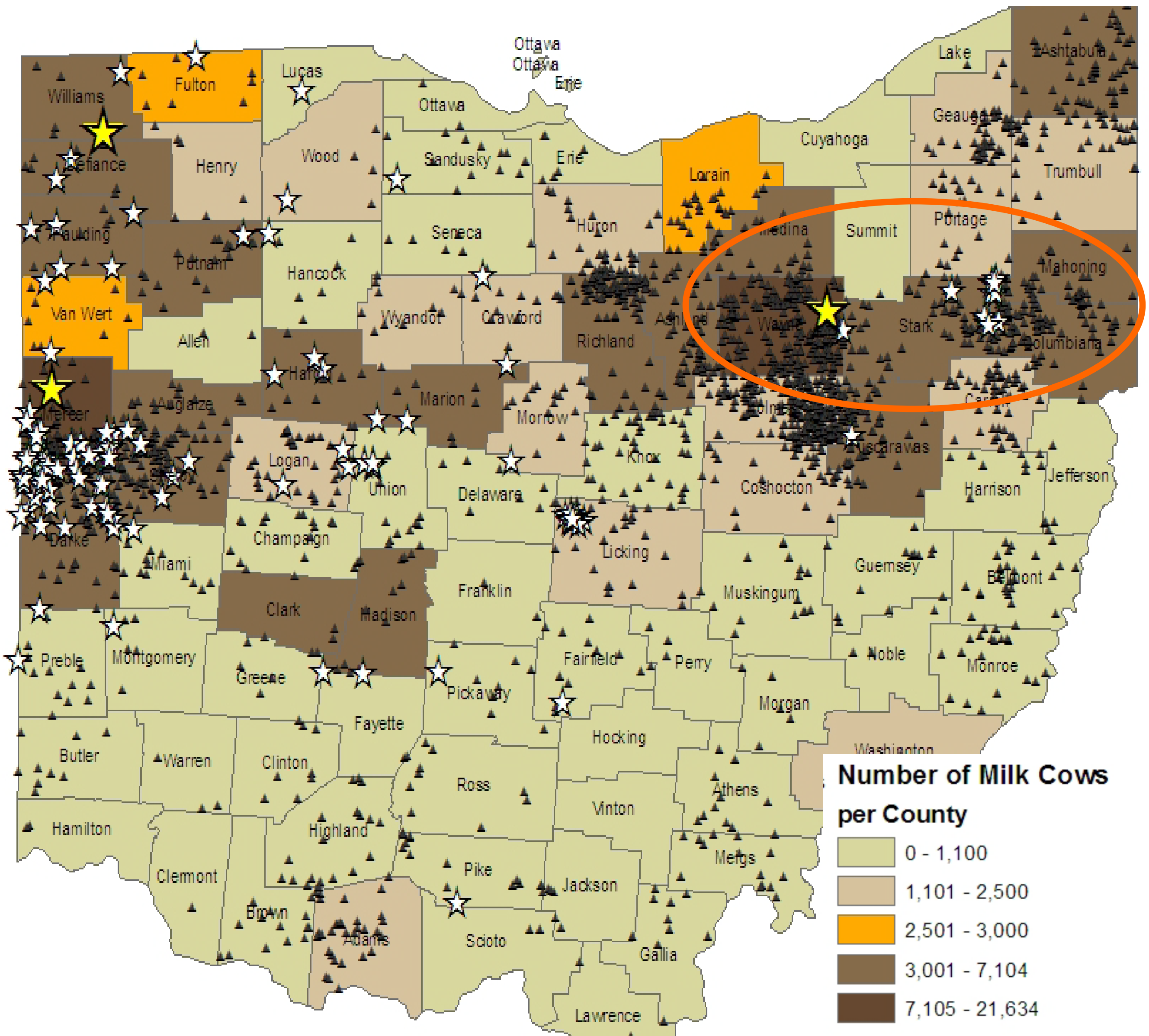


Source: http://www.epa.state.oh.us/portals/35/cafo/FacilityLocations_8x14_061308a.pdf

EXTERNALITIES



EXTERNALITIES



1. Quantified monetary ***value of impact*** (assumed **cost**, could be benefit).

2. Estimated potential **benefits *of reduction of*** impact.

EXTERNALITIES

2000-2001	Mahoning	Stark	Wayne
Number of properties within 3 miles of a dairy	100	147	107
Average proximity of a property to a dairy	0.92	0.64	0.43
Number of dairies within county borders	59	144	628
Number of milk cows (1999)*	4,400	9,200	30,500

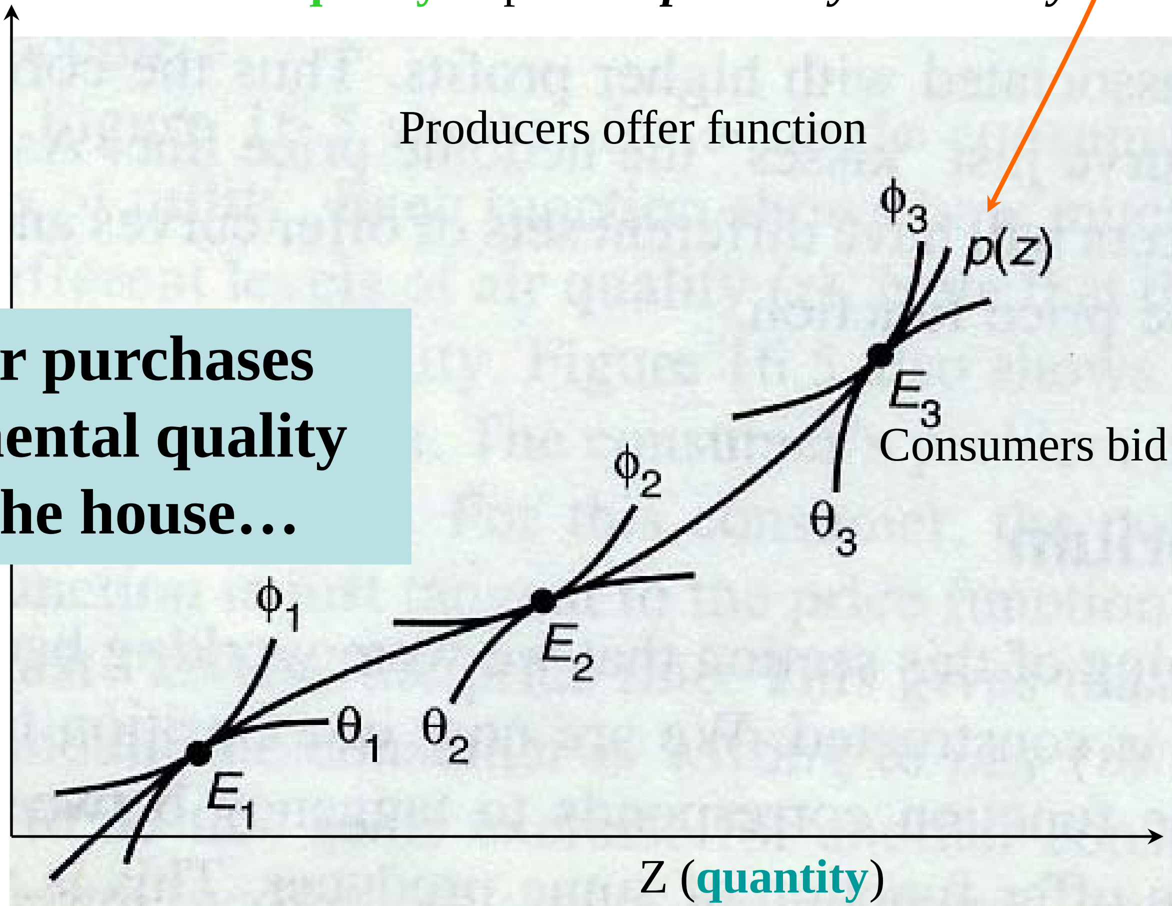
2003-2004	Mahoning	Stark	Wayne
Number of properties within 3 miles of a dairy	121	157	103
Average proximity of a property to a dairy	0.98	0.69	0.45
Number of dairies within county borders	60	116	519
Number of milk cows (2003)*	4,700	9,100	33,300

17% of Ohio's Dairy cattle are found in these 3 counties *(USDA, 2009).*

EXTERNALITIES

Hedonic Price Function

P = **price of environmental quality** = price of ***proximity to amenity*** ***or disamenity***

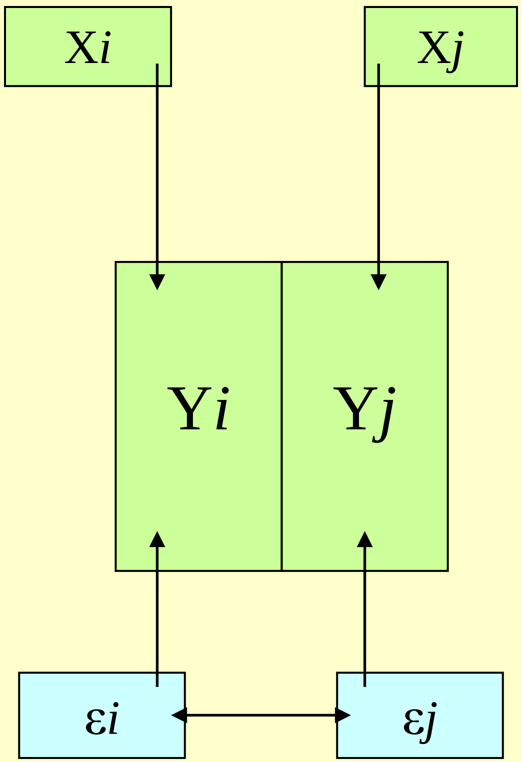


Consumer purchases environmental quality through the house…

* For 3 different consumers/producers

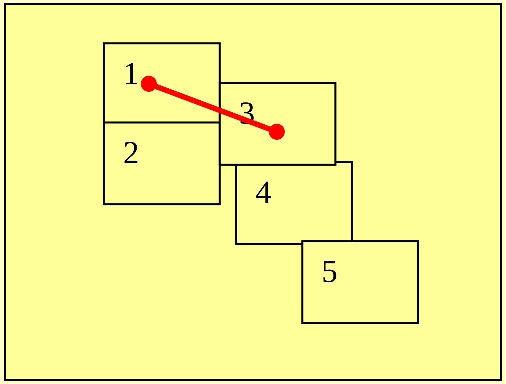
EXTERNALITIES

As an alternative to the lag specification, the interaction may be "located" in the error term so that the model is constructed as…



$Y = \mathbf{X}\beta + \mu,$

$\mu = \lambda \mathbf{W} \mu + \varepsilon \qquad \varepsilon \sim (0, \sigma^2 In)$



Estimated using MLE.

Using OLS would yield inefficient, but ***not*** biased estimates (incorrect significance &fit).

EXTERNALITIES

2000-2001

Variable	Coefficient	Std. Error	Z	Probability
Constant	-722.704	157.209	-4.60	0.000
ln Acres	4.573	2.125	2.15	0.031
Basement (dummy)	13.149	3.247	4.05	0.000
ln Year built	-24.630	11.776	-2.09	0.036
Other structures (dummy)	9.812	4.582	2.14	0.032
ln Bedroom	19.234	6.485	2.97	0.003
ln Full bath	16.996	4.446	3.82	0.000
ln Half bath	22.863	10.891	2.10	0.036
ln Stories	11.154	4.522	2.47	0.014
ln Fireplaces	32.869	7.094	4.63	0.000
ln Living area	33.514	6.165	5.44	0.000
ln Grade	185.171	14.226	13.02	0.000
ln Dist to dairy	**10.403**	**2.499**	**4.16**	**0.000**
ln Dist to city	4.377	3.370	1.30	0.194
ln med. Household income	36.872	7.714	4.78	0.000
ln School quality	43.814	28.136	1.56	0.119
Wayne County (dummy)	-7.646	8.310	-0.92	0.358
Stark county (dummy)	23.246	4.917	4.73	0.000
Lambda	**0.371**	**0.019**	**19.54**	**0.000**

Marginal price = $0.**57** per foot

(2% decline in property value) per mile…

EXTERNALITIES

2000-2001

Marginal price = **$0.57** per foot

Impact: 2% decline in property value per mile (on average)

2003-2004

Marginal price = **$0.51** per foot

Impact: 1.5% decline in property value per mile (on average)

* The results indicate that a **10% increase in environmental quality** consumed at the average (distance) would yield a **$502 benefit to the household.**

* A 25% increase in environmental quality consumed at the average would yield a **$1140 benefit**.

EXTERNALITIES

* A 10% increase in distance for all households, relative to the actual *q* consumed by a household ***across the whole region*** (which includes 10,090 homeowners) would generate a consumer **surplus of $3.975 million.**

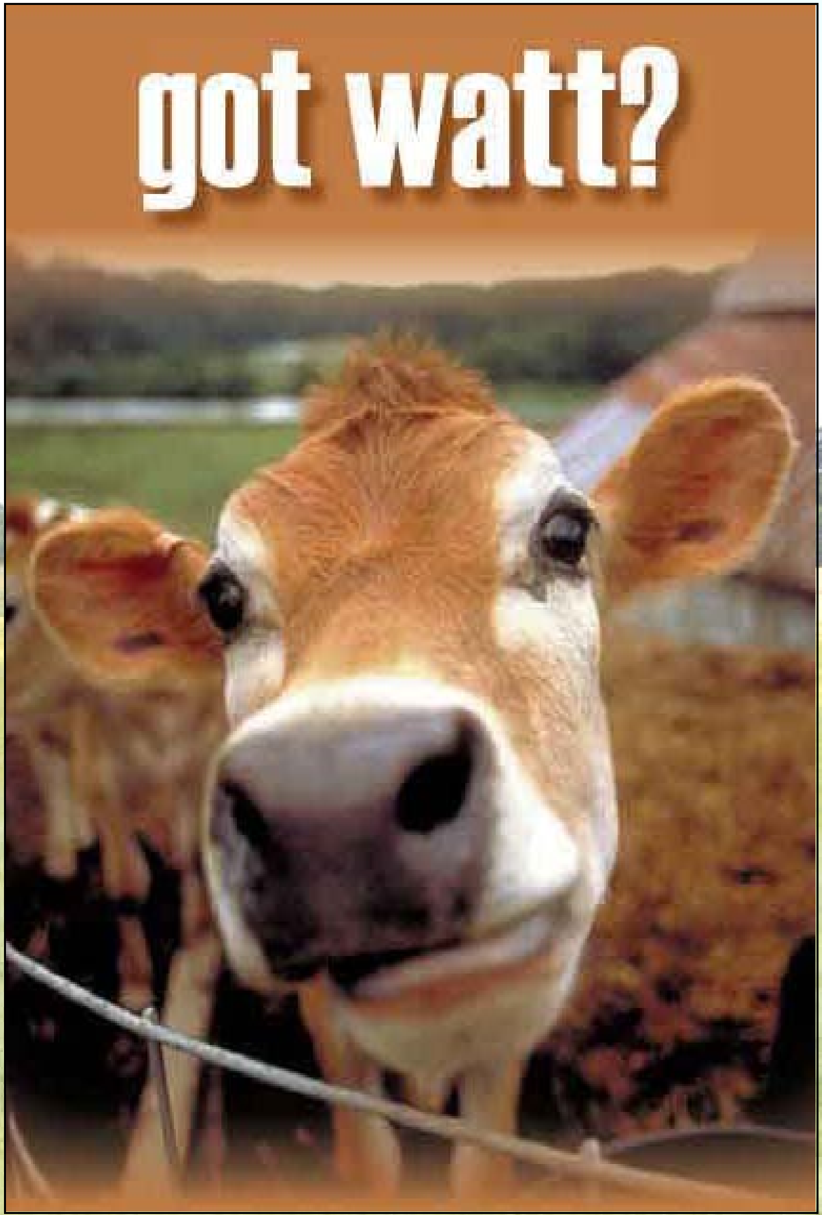
?

Local Estimation of Benefits	**Mahoning**	**Stark**	**Wayne**
Number of properties within 3 m of a dairy ('03)	**121**	**157**	**103**
Benefits to home owners within 3 m…	**$60,742**	**$78,814**	**$51,706**
Number of dairies within county borders ('03)	**60**	**116**	**519**

REMEDY ?

Ghafoori et al. (2006) found that net power generation (on site via biogas produced by an AD system) emits 90% less GHGs than proportional conventional grid production…

(results based upon data derived from a 50,000 head feedlot operation in Canada, *measured via life cycle analysis*).



http://www.nrcs.usda.gov/news/images/gotwattbig.jpg

REMEDY ?

Ohio is currently home to 235,000 dairy cows, which may be capable of producing 958,000 kWh to 1.8 million kWh of electricity per day, and **decreasing emissions** (relative to coal) **by up to 30%** (depending on collection, methane content, and conversion efficiency).

→ **4%**

REMEDY ?

A medium 95-100 cow, 180 animal operation can provide enough power to sustain at least 15 homes (consuming on average over 900 kWh per month).

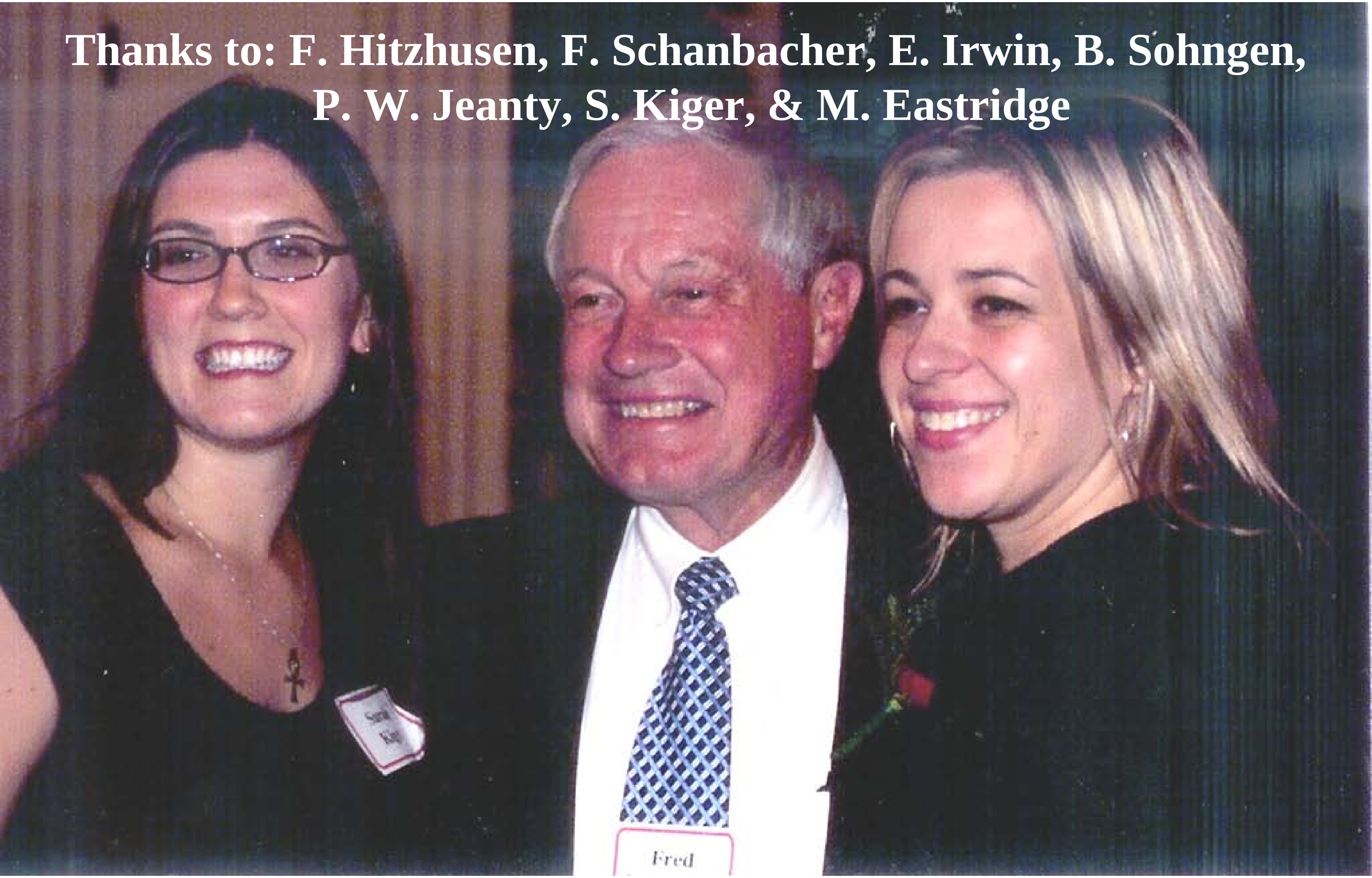
State-wide Annual Emissions (assuming 25% reduction due to treatment by AD, 65% of waste kept in dry, 35% kept in liquid form in storage)

Kg CO_2	**60% methane 25% C**	**coal**	**60% methane 40% C**	**coal**	**70% methane 40% C**	**coal**
Electricity	251,579,746	215,890,370	251,583,309	345,424,592	265,976,935	402,995,357
N2O as CO2 e	282,908,286	377,211,048	282,908,286	377,211,048	282,908,286	377,211,048
CH4 as CO2 e	293,042,567	390,723,423	293,042,567	390,723,423	293,042,567	390,723,423
Enteric	1,817,231,999	1,817,231,999	1,817,231,999	1,817,231,999	1,817,231,999	1,817,231,999
TOTAL	**2,644,762,599**	**2,801,056,840**	**2,644,766,161**	**2,930,591,062**	**2,659,159,788**	**2,988,161,827**
% reduction	7.4%		11.6%		12.9%	

25% collected

→ **1%** power

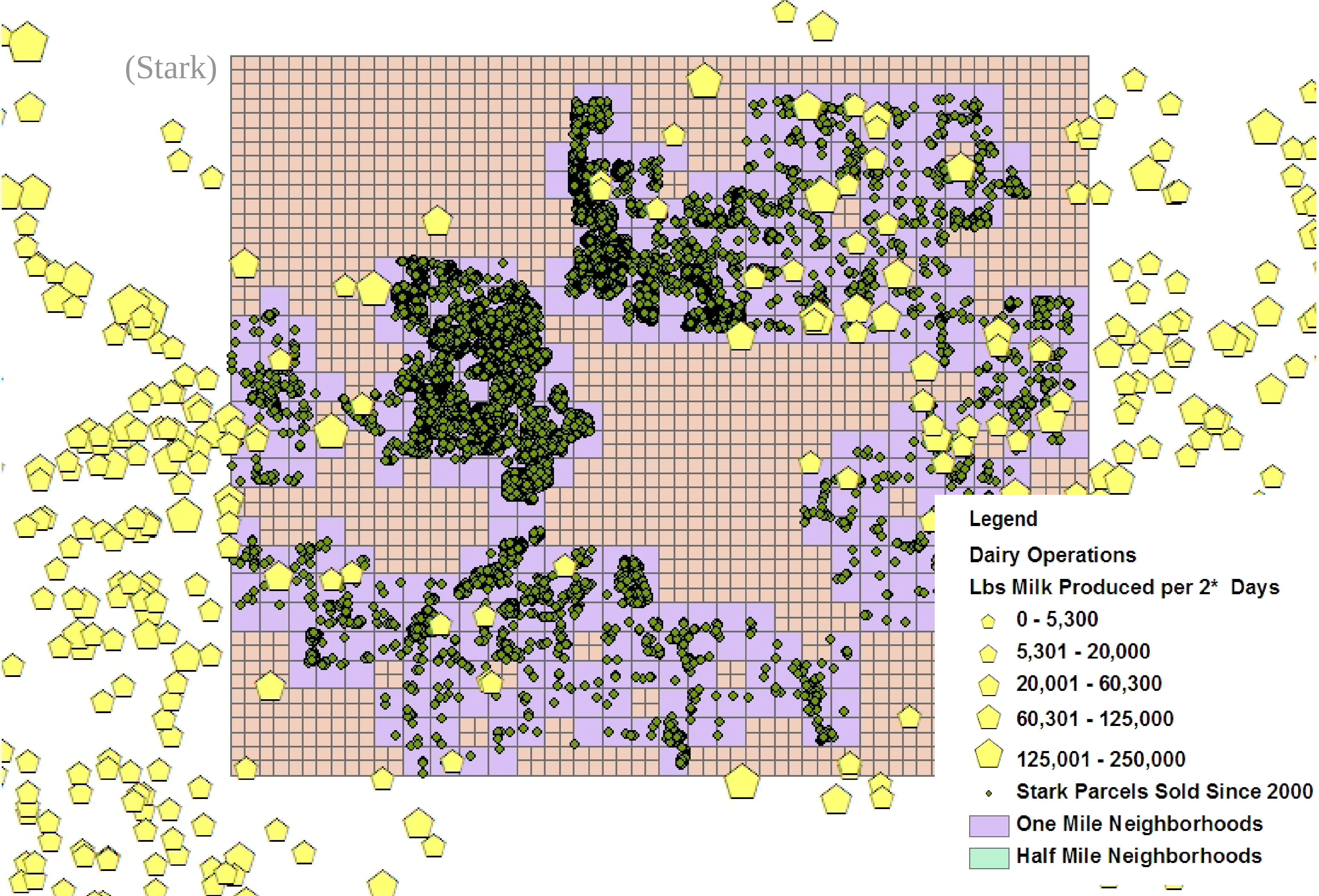
(end)



Funding provided by the U.S. DOE, the Environmental Science Graduate Program (OSU) & the Environmental Policy Initiative (OSU).

Using ***neighborhood*** sampling to address spatial dependence…

(Stark)



Financial & Economic Assessment (spreadsheet)

Number of Neighbors		200
Average distance of neighbor (in feet)	16,260	16,260
Value of externality per foot	0.51	0.51
Value of 10% reduction (WTP estimate)	0	1,000
Externality Reduction Benefits based on MP of externality	829,260	829,260
Externality Reduction Benefits for by value of 25% reducion	0	200,000
Externality Reduction Benefits based on $/cow	0	0
Revenue (Energy & Benefits)	166,368	166,368
Transportation Costs (If relevant)		
Operator Costs	9,125	9,125
Other maintenance expenditures	6,210	6,210
TOTAL OPERATING EXPENSES	15,335	15,335
Operating expenses less avoided costs	15,335	15,335
Revenue less operating expenses	151,033	151,033
Total Depreciation	75,550	65,550
Total Deprecation & Operating costs	90,885	80,885
Interest	0	0
Total cost of depreciation and interest	75,550	65,550
Net returns over system & operating costs	75,483	85,483
Simple Pay Back Period (based on Lazarus, 2007)	***7.6***	***6.3***
Planned Payback (investment/depreciation)	15	15

Greenhouse Gas Emissions (IPCC, 2006)

Substance	Source/ Activity			Emissions (kg per year)	Emissions as CO_2 e (kg per year)
Methane	Animals	Enteric fermentation (TOTAL)	*	17436.80786	366172.9651
		Lactating cows	*	13548.46471	284517.7588
		Dry cows	*	846.7479296	17781.70652
		Heifers	*	2761.955964	58001.07524
		Calves	*	279.6392646	5872.424557
	Manure				
		Anaerobic lagoon		0	0
		Lagoon (LG)		32645.79043	685561.599
		Liquid/ slurry (LS)		8408.764201	176584.0482
		Storage Pond (SP)		19290.69434	405104.5812
		Composting (CM)		247.3165942	5193.648477
		Deep Pit (<1 month) (D1)		0	0
		Deep Pit (>1 month) (D2)		12118.51311	254488.7754
		Stacked Solids (SS)		741.9497825	15580.94543
		Digester (DG)		4946.331883	103872.9695
		Burned for fuel (BF)		4946.331883	103872.9695
		Daily spread (DS)		49.46331883	1038.729695
		Housing:		0	
		Dry lot (DL)			
		Pasture range/ paddock (PS)		494.6331883	10387.29695
		Free stall barn flush		NA	
		Free stall barn scrape		NA	
		(Land application)		NA	
		Manure total		83889.78874	1761685.563

Land based emissions

Measure via:

1. IPCC methodology or,
2. estimate by type of crop and quantity of land in production…

				kg CH4 per ha per year	
		Acres Planted	Hectares Planted	CH_4 Emission Factor	CH_4 Emissions
Corn	Grain	45	18.21085394	-1.5	-27.3162809
	Silage	2	0.809371286	-1.5	-1.214056929
Wheat	Winter	0	0	-1.9	0
	All	10	4.04685643	-1.9	-7.689027217
Forage	*Hay**	15	6.070284645	-1.4	-8.498398503
Soybeans		60	24.28113858	-1.4	-33.99359401
Oats		1	0.404685643	-1.4	-0.5665599
*Tobacco**		1	0.404685643	-1.4	-0.5665599
Tomatos		1	0.404685643	-1.4	-0.5665599
Grass		20	8.09371286	-1.5	-12.14056929
Fallow		30	12.14056929	-0.14	-1.699679701
SUM		185	74.86684396		

IPCC (2006) Soil N Emission Estimation

N_2O_{Direct}--$N = N_2O\text{-}N_{N\ inputs} + N_2O\text{-}N_{OS} + N_2O\text{-}N_{PRP}$

$$N_2O\text{-}N_{N\ inputs} = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) * EF_1 + (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) * EF_{1FR}$$

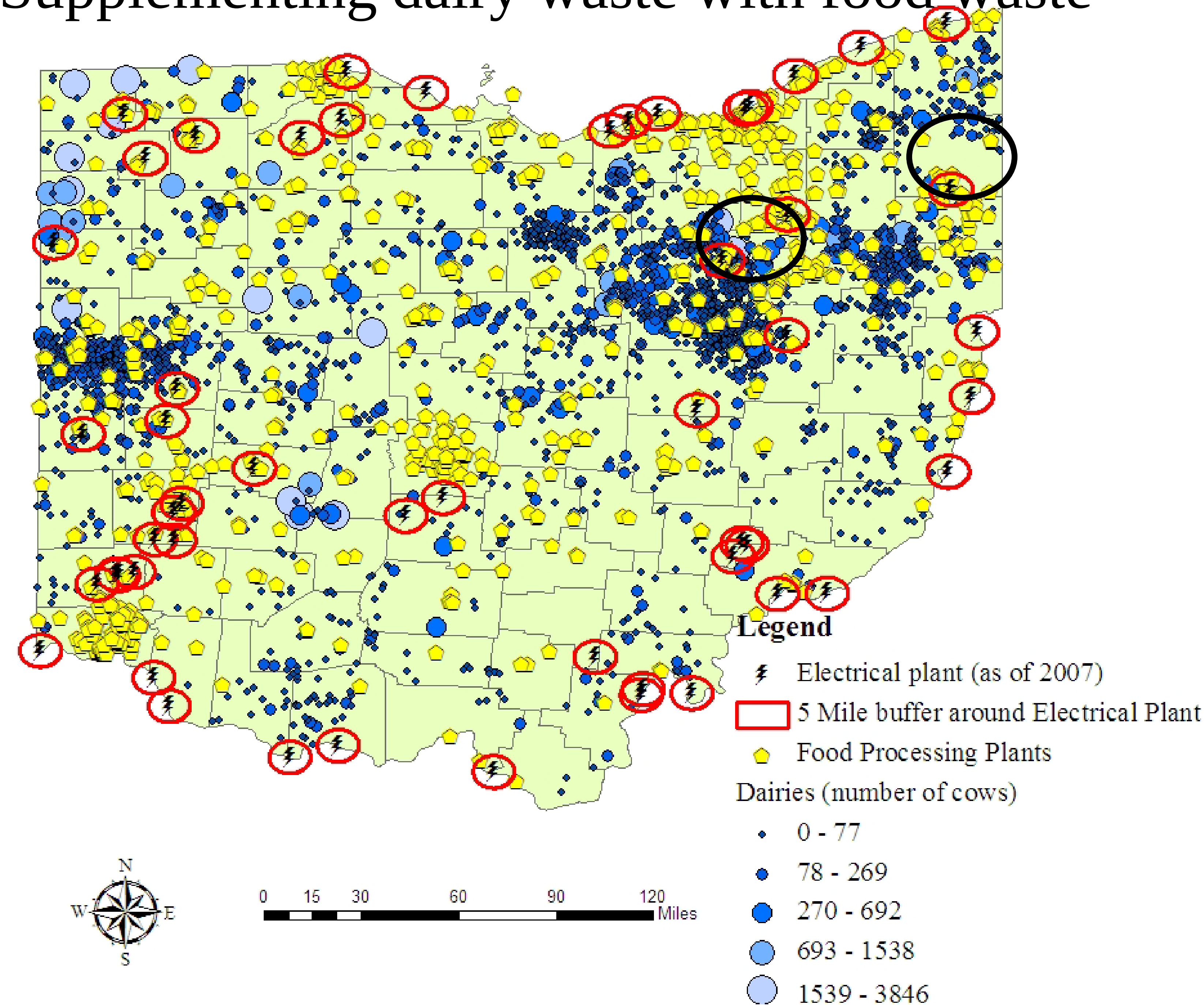
$$N_2O\text{-}N_{os} = \Sigma\,(F_{OS,land,temp} * EF_{2\ land,temp})$$

$$N_2O\text{-}N_{PRP} = \Sigma\,(F_{PRP} * EF_{3PRP})$$

*summing up (above) for all land categories, nutrient quality, and temperature

N_2O_{Direct}-N = annual direct N_2O-N emissions produced from managed soils, kg N_2O-N per year	*estimated from input/data below*
N_2O-N $_{Ninputs}$ = annual direct N_2O-N emissions from N input to managed soils, kg N_2O-N per year	*estimated from input/data below*
N_2O-N_{OS} = annual direct N_2O-N emissions from managed organic soils (kg N_2O-N per year)	*estimated from input/data below*
N_2O-N_{PRP} = annual direct N_2O--N emissions from urine and dung inputs to grazed soils (kg N_2O-N per year)	*estimated from input/data below*
F_{SN} = annual amount of **synthetic** fertilizer applied to soils (kg N per year) **E**	? can assume 150lb/acre for corn etc. (based on yield data from NASS)
F_{ON} = annual amount of animal manure, compost… applied (kg N per year) **E**	? can estimate on a case by case basis (as proportion of manure produced ?)
F_{CR} = annual amount of N in crop residues (above & below ground) returned to soils (kg N per year)	?
F_{SOM} = annual amount of N in mineral soils that is mineralized, is association with loss of soil C from soil organic matter as a result of changes to land use or management (kg N per year)	?
F_{OS} = annual area of managed/drained ***organic*** soils (ha)	75 (average size of Ohio farm)
F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (kg N per year) **E**	? can estimate by taking proportion of total produced assumed to be left outside
EF_1 = is the emission factor for N_2O emissions from N inputs, kg N_2O-N per kg N input	0.001 (IPCC default)
EF_2 = is the emission factor for N_2O emissions from drained/managed ***organic*** soils, kg N_2O-N per kg N input	8 (IPCC default)
EF_{3PRP} = emission factor for urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O-N per kg N input	0.02 (IPCC default)

Supplementing dairy waste with food waste



Energy & Emission Generation

Cuellar and Webber (2008)

Energy: 1 m^3 biogas → 36 MJ/m^3 * 1 kWh/3.6 MJ * 0.60 * 0.25 = 1.5 kWh.

The total amount of carbon dioxide produced from one cubic meter of biogas can be determined by the following equation:

$$kg\ CO_{2\ (total)} = 1\ m^3 biogas * (X\%CH_4 * 0.65\ kg/m^3 * 2.75 + 1.8\ kg/m^3 (1 - X\%CH_4)),$$

where 0.65 kg/m^3 is the density of methane, and 1.8 kg/m^3 is the density of carbon dioxide. The methane component of the equation is multiplied by 2.75 because this is the ratio of the mole weight of carbon dioxide to methane (2.75 kg of CO2 is produced from the combustion of 1 kg of CH4).

Energy & Emission Generation: Efficiency/Conversion Scenarios

Scenario	Methane content & conversion efficiency	Conversion efficiency	kg CO_2 produced per kWh	Total kWh produced (daily)	Homes serviced
A	**60%**	**25%**	**1.13**	**107**	**3.5**
B	60%	40%	0.71	200	6.5
C	70%	40%	0.64	171	5.6

Less efficient than coal…

Table 4.12 Emission factors & potential biogas generated electricity yield scenarios at the farm level (for a 183 animal operation), assuming all waste material was collected.