DAIRY MANURE STORAGE:

GHG MITIGATION & ADAPTATION TO BUILD FARM RESILIENCY

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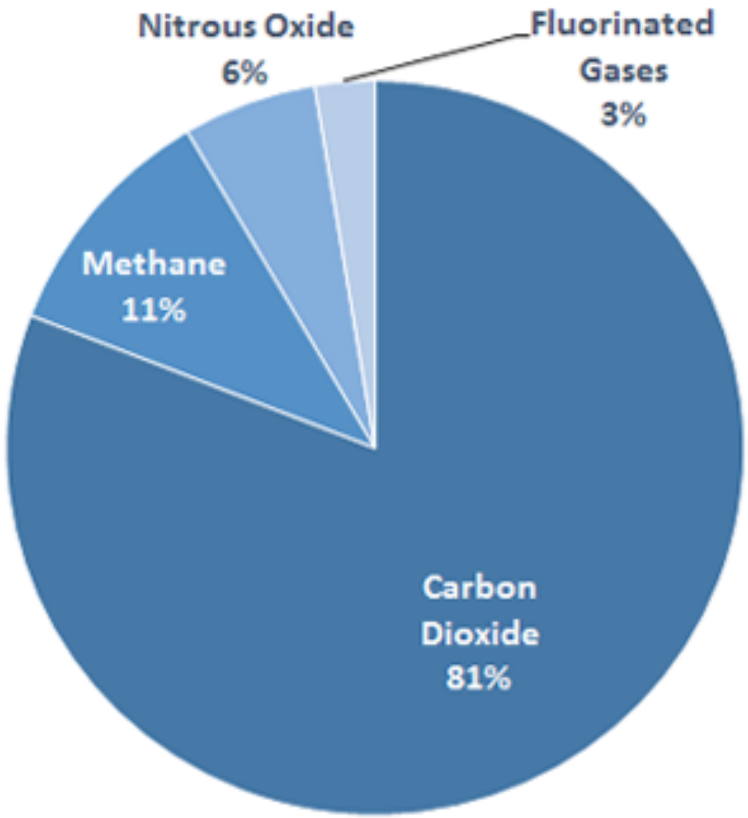
March 2018
Northeast Climate Hub Partners Meeting – Building Ag Resiliency

Goals for building Farm Resiliency

- Today I will present Dairy Farm Manure Mitigation that also builds Farm Adaptation and Resiliency to a changing climate

- Focus on Dairy Manure

Across the Nation, Most GHG comes from CO_2



GHG by type and sector (Source: US EPA 2016)

On-farm, Common Farm & Forest Greenhouse Gases (GHG) include:

- **Carbon Dioxide (CO_2)**
  - – e.g. combustion of fossil fuels, forests
- **Methane (CH_4)**
  - – e.g. cow rumen, manure
- **Nitrous Oxide (N_2O)**
  - – e.g nitrogen fertilizer

Different GHG have different Global Warming Potential (GWP)

Global Warming Potential (GWP)

- The Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases.
  - a relative measure of how much heat a greenhouse gas traps in the atmosphere.
  - It compares the amount of heat trapped by a gas to CO_2
  - GWP of CO_2 =1 CO_2equivalents, the common unit: CO_{2e}

- Different GHGs can have different effects on the Earth's warming.
  - their ability to absorb energy (their "radiative efficiency"),
  - how long they stay in the atmosphere (their "lifetime").

GWP over time – relative to CO_2

gas	Lifespan (years)	GWP 20 year model	GWP 100 year model	GWP 500 year model
CH_4	12.4	86	34	7
N_2O	121	268	298	153

From 2013 IPCC AR5, p714

Global Warming Potential (GWP)

- From my previous work with John Duxbury
  - NY Dairy accounting for
    - Feed, Transportation, Enteric, Manure Management

- CO_2 accounts for 25% of milk emissions
- CH_4 accounts for 53% of milk emissions
- N_2O accounts for 22% of milk emissions

- CH4 and N20 account for 75% of dairy farm emissions
- Manure management accounts for 23% of dairy farm emissions

Dairy Manure: Focus on CH4 and N20

Manure Management

- Manure components
  - Nitrogen leads to production of nitrous oxide (N_2O)
  - Volatile solids (VS) lead to the production of methane (CH_4)

- ANAEROBIC (lo Oxygen conditions) Manure Storage
  - Convert VS -> CH4
  - Prevent N conversion to N2O
- AEROBIC (hi Oxygen conditions) Manure Storage
  - Prevent VS-> CH4
  - Promote N conversion to N2O

  - GWP of CH4 = 34
  - GWP of N2O = 298

Manure Management

Daily Spread

- AEROBIC
  - Bad for water quality
  - Hi N-loss from winter field application
- Low CH_4 production

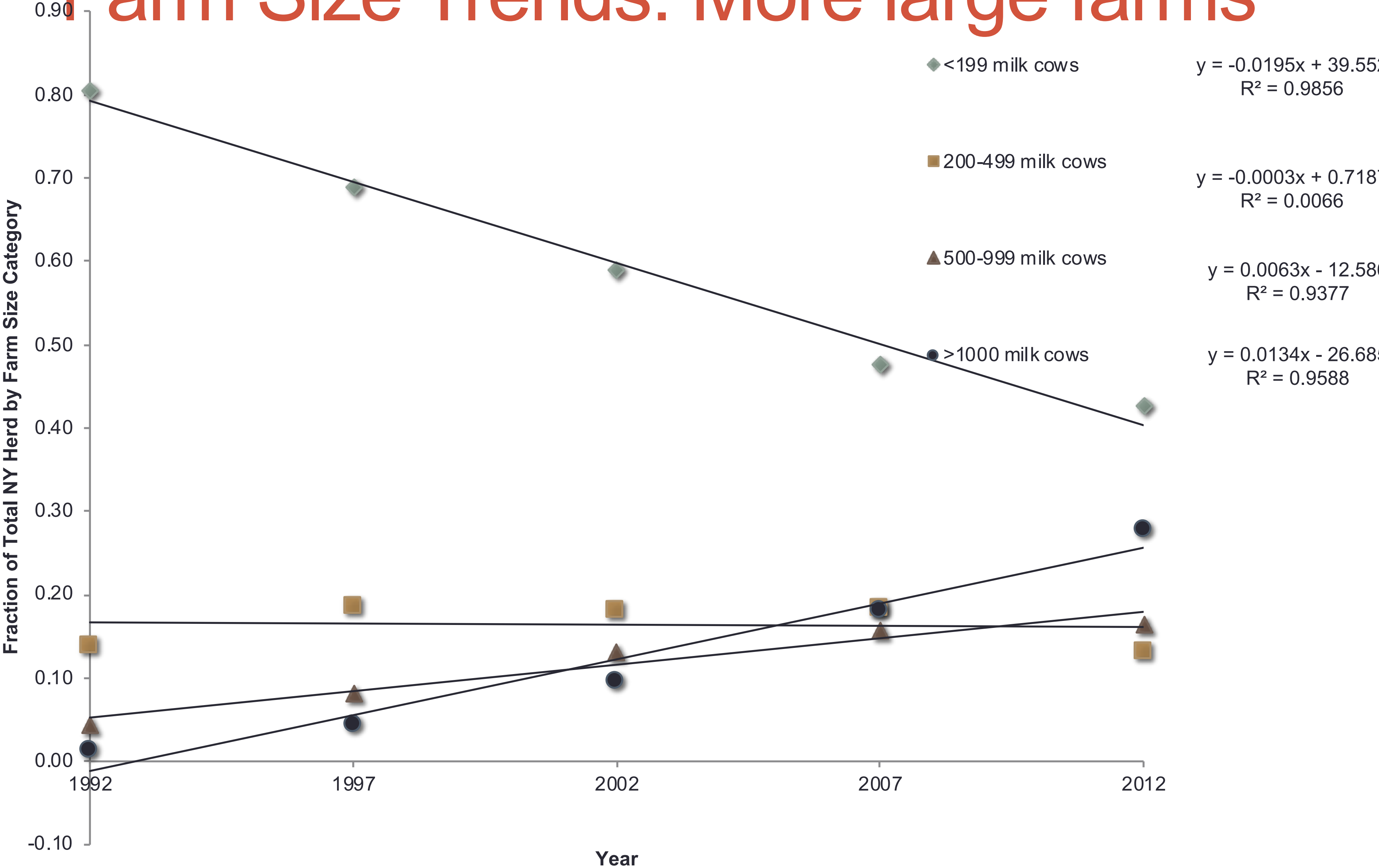
Liquid Storage

- ANAEROBIC
  - Good for water quality
  - Hi N-retention for spring planting
- High CH_4 production

Research CONTEXT:

- Work from a HATCH-FCF/USDA proposal
- Farm size increasing
- Logistics of larger farms, BMPs, and CAFO rules forcing more manure storage to protect water quality
- Anaerobic storage of manure increases CH4
  - How do policies to improve water quality impact GHG emissions from dairy farms?
  - Is there cost effective ways for addressing these new GHG emissions?
  - Does Extreme Weather events threaten water quality with manure storages?

Farm Size Trends: More large farms

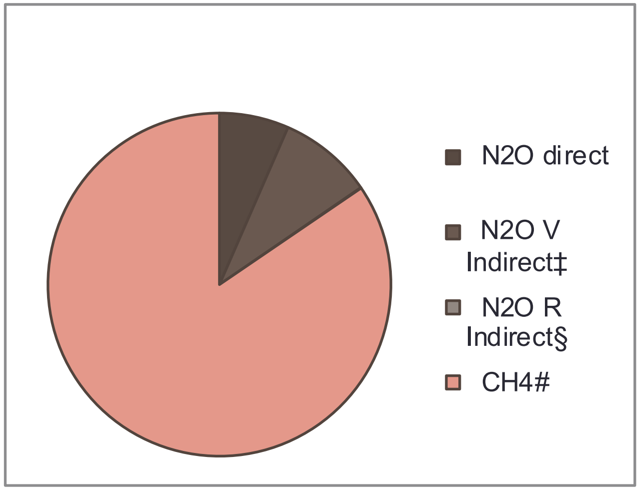


Emissions across Management type

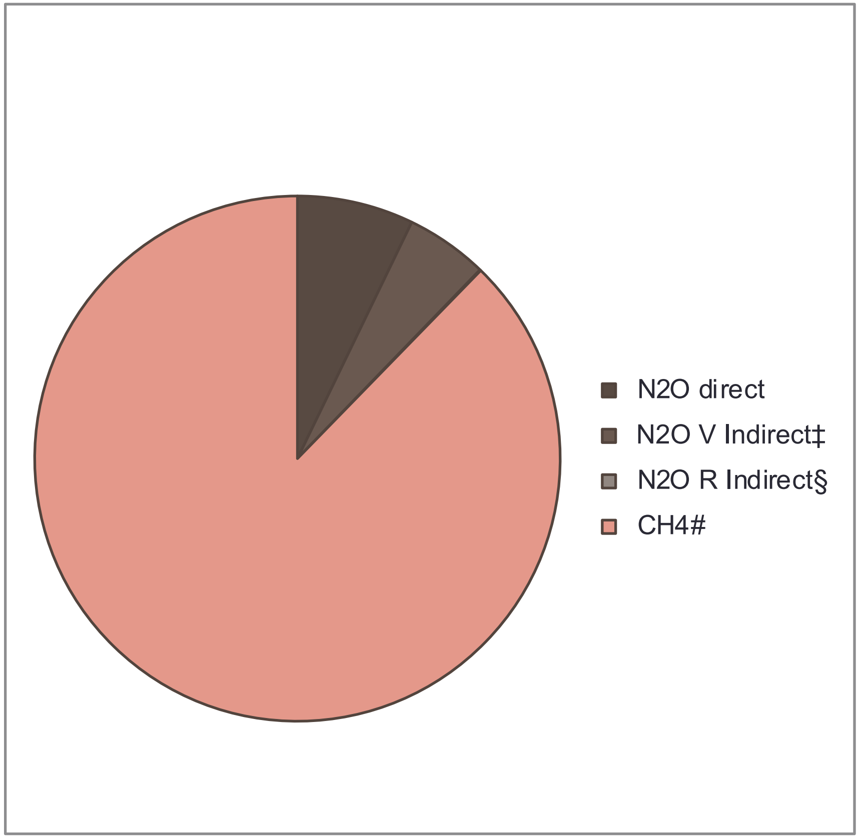
	Daily Spread†	Solids	EPA-$_{LS}$ Liquids#	Total	
	$MgCO_2e$ /yr	$MgCO_2e$ /yr	$MgCO_2e$/yr	$MgCO_2e$ /yr	% GHG
1992					
% WMS	80.6%	3.6%	15.8%		
N_2O direct	0	11,427	49,572	60,999	8.7%
N_2O V Indirect‡	50,736	6,171	25,778	82,684	11.8%
N_2O R Indirect§	0	0	521	521	0.1%
CH_4#	52,016	18,745	487,907	558,668	79.5%
1992 TOTAL	102,752	36,342	563,777	**702,872**	
2012					
% WMS	42.6%	10.7%	46.6%		
N_2O direct	0	28,641	124,251	152,892	9.9%
N_2O V Indirect‡	22,709	15,466	64,610	102,786	6.6%
N_2O R Indirect§	0	0	1,305	1,305	0.1%
CH_4 #	23,282	46,982	1,222,913	1,293,178	83.4%
2012 TOTAL	45,992	91,090	1,413,078	**1,550,160**	

CH_4: 80% of manure mngmt emissions
more anaerobic storage = more CH_4

1992: 703,000 Mg CO_2e



2012: 1.6 million Mg CO_2e



Policies to Promote Water Quality

- By storing manure,
- There was a doubling of GHG emissions from dairy farms from 1992 to 2012.

- It's a beautifully complicated system!

Comparing 1992 and 2012 Herd and Manure Practices – CH_4 only

	Animal units	Milk produced	Methane Produced‡	
	Num.	Mg	Mg CO_2e /yr	Mg CO_2e /Mg milk
1992 Herd total	1,414,436	5,246,878	558,668	0.11
2012 Herd total	1,197,601	5,988,260	1,293,178	0.22
2012 Herd with 1992 WMS†	1,197,601	5,988,260	473,023	0.08

Increases in dairy efficiency have reduced the CH_4 production *Potential*

- 2012 herd
  - Produced 14% more milk
  - With 15% fewer animal units
  - The 2012 herd reduced the Methane Production Potential

but increased anaerobic manure storage, increased the overall methane produced

- Anaerobic Storage of Manure!

A Scenario

- What if manure storage was covered and equipped with a flare?

Fortunately, Liquid storage is Primed to address Water and GHG

- Liquid storage
  - Retains N for spring planting (great, you reduce N fertilizer purchase, you can apply at specific times)
  - Locates all the volatile solids (VS) in one place to capture CH4

- With a Cover and Flare system
  - You can capture the CH4 that is produce and destroy it

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Flaring Methane turns it into CO_2 which has a GWP of 1.

  - You can burn that CH_4 for energy generation in an Anaerobic Digester System (ADS)
    - Capture and destroy the methane
    - Displace Fossil Fuels

Image of a cover – Fessenden Farm

Scenario: Storage Assumptions

	Storage volume† million liters	Surface Area m^2	4-mo. Storage Num. of cows‡	6-mo. Storage Num. of cows‡	10-mo. Storage Num. of cows‡	12-mo. storage Num. of cows‡
Large cover	14.5	4,274	1500	1000	600	500
Medium cover	8.0	2,351	825	550	330	275

Cover+Flare Costs

Budget Category†	1000 Cow Cover # USD	550 Cow Cover # USD
Equipment	$221,081	$121,595
Personnel	$22,694	$22,694
Fringe	$2,705	$2,705
Travel	$3,136	$3,136
Supplies	$890	$890
Contractual	$20,947	$20,947
Other	$14,545	$14,545
SubTotal	$285,999	$186,513
Separator	$46,613	$46,613
Cover Disposal	$34,503	$18,977
Rain water (savings/10yr) ‡	-$62,031	-$34,117
Interest (10 yrs at 4.5%)	$74,337	$53,115
Total Cost	**$379,422**	**$271,100**
cost per milking cow/yr	$37.94	$49.29
cost per Mg CO_2e§	$9.63	$12.51

Costs

Cover + Flare

- ~$300k
- Reduces odor
- Improves N management
- Prevent extreme weather events,
- Reduces hauling
- Decreases GHG

Anaerobic Digester System (ADS)

- ~$1 million
- Reduces odor
- Improves N management
- Prevent extreme weather events
- Reduces Hauling
- Decreases GHG
- AND
- Generates electricity

Why am I so passionate about CH_4 destruction as a constructive next step?

Because CH4 is SUPER POTENT, short-lived molecule => Impact FUTURE Farms

gas	Lifespan (years)	GWP 20 year model	GWP 100 year model	GWP 500 year model
CH_4	12.4	86	34	7
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Because increase in temperature

- Will increase methane emissions from dairy manure
- Therefore any cover and flare will be even more cost effective with time

Because Increases in Precipitation

- Can cause uncovered storages to have OVERFLOW Events.

- For Example, in NY Winter/Spring 2017, there was unusual volumes of precipitation
- This maxed out storage space
- There were ~15 OVERFLOW events – contaminating water resources.

- One might also imagine what happened to the farms that continue to daily spread.

Because some farmers are voluntarily doing it for other reasons

- Odor control
- Community relations
- Increased storage capacity (bc it doesn't have to account for rainfall)
- Decreased Hauling costs (bc they don't haul the water)

- Additionally, it's a helpful step towards developing Anaerobic Digester System (ADS) when the price for the energy makes ADS more cost effective.

REAL, ADDITIONAL, PERMANENT, VERIFIABLE

To Receive Federal, State or Local Funding, Projects should be

- REAL: actual emissions reductions
- ADDITIONAL: an action that goes beyond business as usual
- PERMANENT: non-reversible
- VERIFIABLE: readily and accurately quantified

We want our Tax Dollars to WORK, fast, and effectively to SLOW the curve

PRACTICE	Real ?	Additional ?	Permanent ?	Verifiable ?	Positive Impacts for adaptation
Dairy Feed Management • reduces the enteric methane emissions • reduces amount of manure produced, thus reducing production of manure methane	YES	NO (it's a cost savings)	Yes	Difficult	• water quality • Decreased $inputs • Increased milk profitability • Reduced land area requirement (for growing and manure application) and downstream impacts • Reduced manure spreading • GHG reduction

PRACTICE	Real ?	Additional ?	Permanent ?	Verifiable ?	Positive Impacts for adaptation
Reduce N in diet	Yes	Yes	Maybe	Difficult	• water quality • Reduced N manure storage N2O and field N2O emissions

PRACTICE	Real ?	Additional ?	Permanent ?	Verifiable ?	Positive Impacts for adaptation
Separated Solids with roof • Possible CH4 mitigation but likely negated by N2O emissions	NO	NO	Maybe	Difficult	• water quality for extreme weather events

PRACTICE	Real ?	Add ?	Perm ?	Verify ?	Positive Impacts for adaptation
Separated Manure Liquid Storage with Cover & Flare	YES	YES	YES	YES	• water quality • Neighbor relations (odor) • Reduced rainwater • Reduced manure hauling costs • No OVERFLOW events with extreme weather events • Increased storage capacity • Increased N-retention for well-time field application • Possible gravity fed irrigations • Increased N-field application timing • Decreased need for expensive energy-intensive synthetic N • Reduced GHG • Increased temperature = increased emissions = increased long-term mitigation potential • NY funding

PRACTICE	Real ?	Add ?	Perm?	Verify ?	Positive Impacts for adaptation
Anaerobic Digester System	YES	YES	YES	YES	• water quality • Neighbor relations (odor) • Reduced rainwater • Reduced manure hauling costs • No OVERFLOW events with extreme weather events • Increased storage capacity • Increased N-retention for well-time field application • Possible gravity fed irrigations • Increased N-field application timing • Decreased need for expensive energy-intensive synthetic N • Reduced GHG • Increased temperature = increased emissions = increased long-term mitigation potential • NY funding • Renewable energy/ energy self-sufficiency

My Top 4 Practices for whole farm resiliency – short and long-term

- Farm Forests
  - 30% of NY farm land is in forests
  - Long-term profitability AND GHG mitigation
- CH4 destruction on Dairy Farms
  - Cover+Flare: Very effective GHG destruction, addresses neighbor relations, and prevents overflow events in case of extreme weather event
  - (ADS too, but less cost effective)
- N-use efficiency
  - Save energy from synthetic N
    - Improves profitability
    - Reduces GHG at the site of N-production
  - Improves water quality, Reduces field N-emissions
- Renewable Energy

Project Materials

Tier II Worksheets Identifying Farm & Forest GHG Opportunities

Information Sheet	**Topic**
IS#1	Intro to Farm & Forest GHG
IS#2	Dairy Manure Storage
IS#3	Planning for Quantitative Methane Capture and Destruction f
IS#4	Energy Efficiency
IS#5	Nitrogen Fertilizer Management
IS#6	Soil Carbon Management
IS#7	Forest Management

AEM Technical	Water Quality BMPs
Tools	http://www.nys-soilandwater.org/aem/techtools.html

- Jenifer Wightman
- jw93@cornell.edu

- Please find our Outreach and Peer-reviewed work
  http://blogs.cornell.edu/woodbury/

Anaerobic Digester System (AD or ADS)

- Patterson Farm, NY 980 dairy cow farm
- Anaerobic Digester cost $1.5 million
  - Received 1.2 million in grants.
- $80,000 saved electricity/yr
- $40,000 spent on upkeep (oil, repairs, labor)
- $40,000 x10 years is $400,000
- Controls odor, keeps out rain, receives tipping fees from food wastes, H_2S corrosion of parts

AD: Relative GHG Benefit

- The benefit from producing electricity
  - at 0.24 kg CO2e/kwh
  - 152 Mg CO2e/ year by displacing fuels used in grid electricity
- This is 4% of the GHG benefit of methane destruction + fossil fuel mitigation.
- CH4 destruction is 96% of the GHG mitigation benefit, NOT the renewable fuel

- This is not to devalue the benefit for the renewable fuel, but energy self-sufficiency is a very different benefit than GHG mitigation

Milking Cows and Storage

Year	Total cows† Num.	Farms (>200 cows) Num.	Farms (>200 cows) % Total	Cows (on farms>200) Num.	Stored Manure‡ % Total	Daily Spread‡ % Total	Stored as Liquid‡§ % Total
1992	721,286	413	4%	139,819	19%	81%	16%
1997	700,480	570	7%	217,599	31%	69%	25%
2002	670,003	576	8%	274,265	41%	59%	33%
2007	626,455	591	10%	327,983	52%	48%	43%
2012	610,712	503	9%	350,449	57%	43%	47%
2017	577,235	591	21%	421,516	73%	27%	59%
2022	547,718	611	35%	474,681	87%	13%	70%

1992 EPA report (from NYS survey) indicated 20% liquid manure, 70% daily spread
2012 paper by Q. Ketterings indicates 61.9% of farms >200 have 6 mo storage, 46% of all farms

How Do We Manage our Landscape for GHG and make Food Feed Fiber Fuel?

- Reduce SOURCE of Emission – change methods
- Move Emissions into SINKS/Products – increase yield
- DISPLACE Fossil Emission – produce renewables
- DESTROY Methane – reduce the Global Warming Potential (GWP) of CH_4 and generate renewable energy

The Benefits of Soil Carbon

- While often touted as a great sink for carbon, soil carbon MOVES quickly. NOT permanent.

- Soil carbon can temporarily store carbon, but the real benefits in relation to climate change are:
  - Adaptation to extreme weather events (by improved water retention for drought, improved infiltration during flooding, reduced erosion and impacts on water quality)
  - Increased crop productivity and cropping efficiency (reducing energy to produce crops and associated emissions)

- See IS-6 and IS-7

Nitrogen Management (IS5)

- Nitrogen is essential to plant growth
- Nitrogen occurs in several forms in the soil, is readily transported by water, and volatilized to the air.
- Nitrous oxide (N_2O) is produced as part of the nitrogen cycle in soils.
- As a result, N-loss can cause water pollution, air pollution, and climate change.

- Because N_2O has a GWP of 298, it is a meaningful gas to manage farm GHG.

Nitrogen in manure

- Nitrogen in manure can be managed somewhat by managing N in diet
- Nitrogen favorably partitions to the liquid portion of the manure.
- Anaerobic storage of manure over the winter (instead of land application) retains the N for spring application.

Nitrogen Management Opportunities

- Know where your N is located
  - in your manure
  - in your soils
  - from your crop rotations and cover crops
  - Develop and use a comprehensive nutrient management plan.
  - This will help optimize yields and reduce losses
- Reduce Synthetic N
  - Manufacturing synthetic N uses LARGE amounts of energy
  - (saves GHG from production emissions! And saves money)
- Store winter Manure-N in Anaerobic conditions
- Follow the 4-Rs for N-application

Four R’s of N-management

- Right Source
  - Replace anhydrous ammonia with other N-formulations will reduce emissions
- In the Right Place
  - Get samples tested so you know what you need to add and where
- With the Right Rate
  - Applying ‘extra-N’ as ‘insurance’ can cause greater emissions to air, water and climate change while also throwing away money.
- At the Right Time
  - Don’t apply N in the fall (most is lost during the winter)
  - With Manure (store anaerobically and you’ll have lots in the spring)
  - Applied as close to the growing season as possible
  - Avoid wet and rainy conditions

The Benefits of N-management

- Well managed N,
  - Reduces fertilizer costs and increases crop efficiency
  - Reduces fertilizer purchase (and GHG from N-manufacture)
  - Reduces impacts to air, water, and climate change.

- See IS-2 and IS-5

Energy Efficiency Opportunities (IS4)

- Most energy currently comes from fossil fuels.
- As a result, any industry that uses fuel, is contributing to the global CO_2 emissions.

- While farms can produce their own energy (e.g. solar panels or anaerobic digestion systems for generating renewable energy), Energy Conservation and Efficiency improvements can save money and energy Now and Into the Future

- Farms are very different, so the following are general suggestions for thinking about how to proceed.

Forest Management Opportunities (IS7)

- 30% of farmland is forested.

- 63% of NY is forested (19 million acres)

- Improved forest management
  - Can increase carbon-sequestration per acre (soil and stem)
  - Can increase bioenergy products to displace fossil fuels
  - Can provide increased income for sale of long-lasting wood products