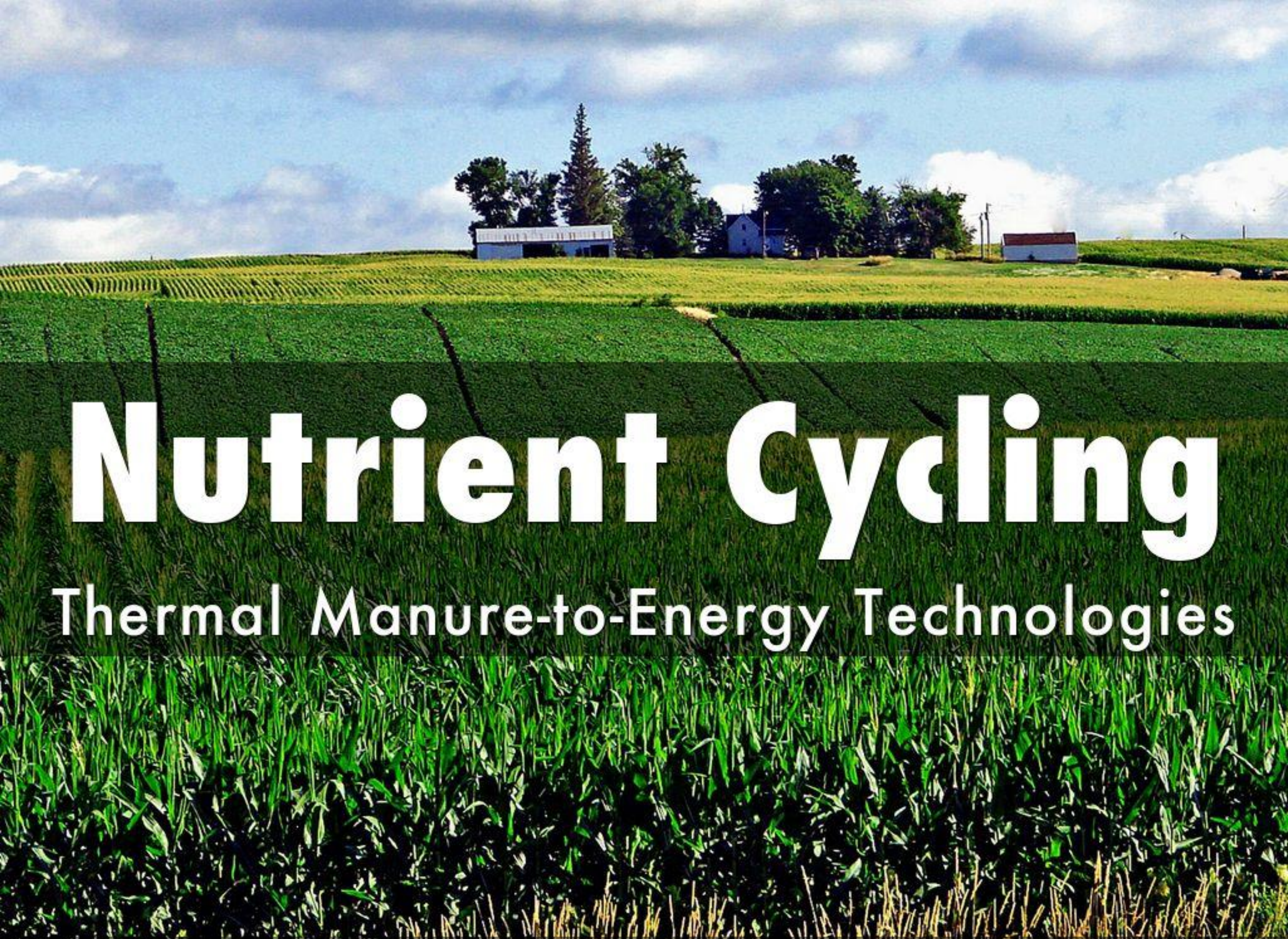

Nutrient Cycling
Thermal Manure-to-Energy Technologies

Farm Manure-to-Energy Initiative

Kristen Hughes Evans, Sustainable Chesapeake

Dr. Mark Reiter, Virginia Tech Eastern Shore Agricultural Research & Extension Center

Long-Distance Transport of Excess Manure P

Cost-effective Technologies that Generate Revenue for Farmers

Farm Manure-to-Energy Initiative

- Farm Demonstrations
- Performance Evaluations
- Communicatons – website, information sharing, training, workshops
- Market development for ash/biochar

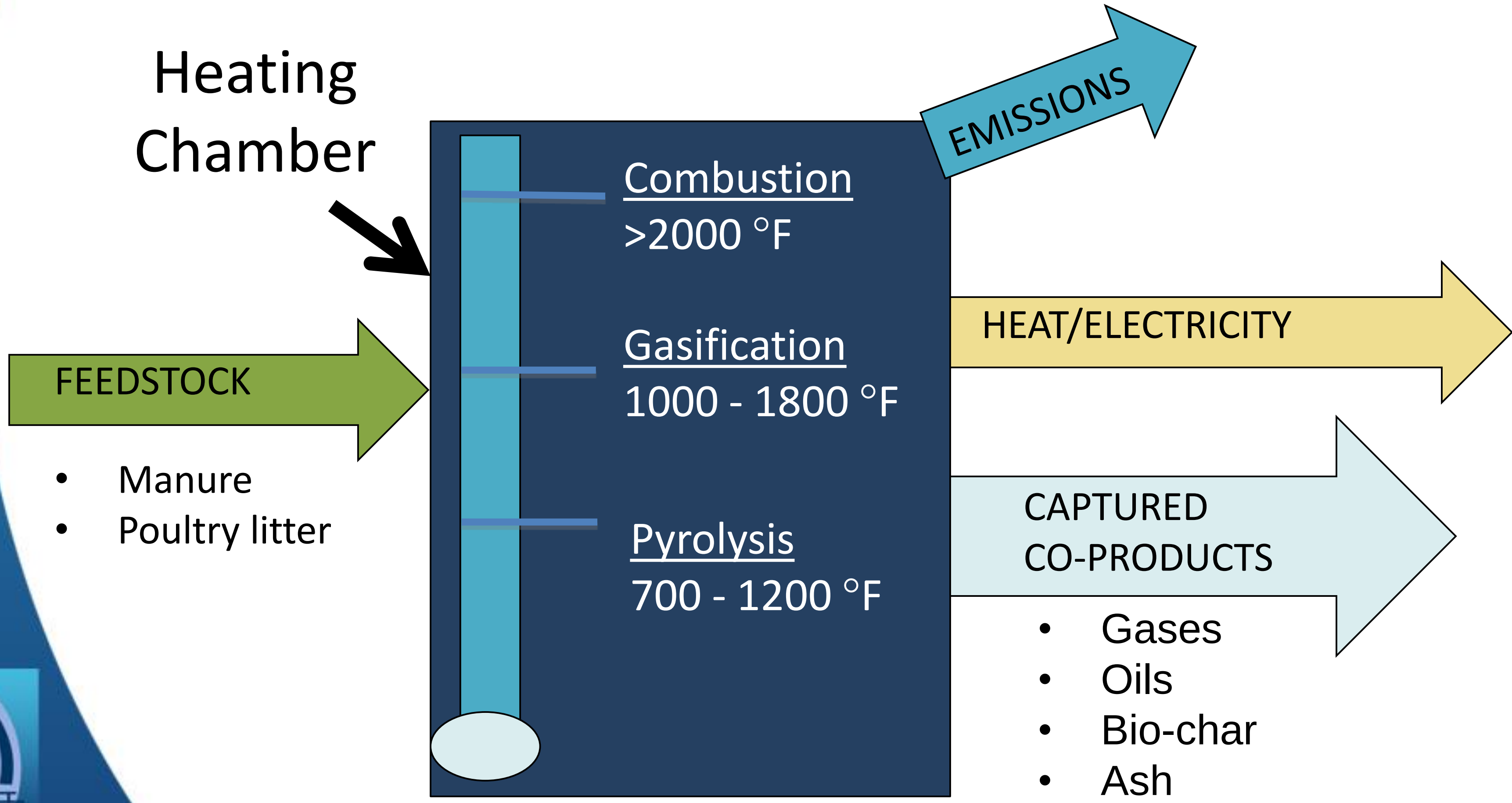
Environmental Performance

Nutrient Cycling: Air Emissions and Ash/Biochar

Air Emissions
NOx and NH3

- Data on 5 technologies (pyrolysis, gasification and combustion)
- All 5 include NOx
- Only 2 include NOx + NH3
- Farm M2E data available in spring/summer 2015 on at least 2 additional technologies.

Thermochemical Conversion



FPPC

Virginia Tech Pyrolysis

Prototype Unit - Data on NOx + NH3

VT Pyrolysis Emissions Results

- Problem: Testing on syngas
- Syngas typically used for fuel
- Combusting syngas = reduced emissions?
- Without combustion of syngas...
- N emissions are high (70% of poultry litter N)

BHSL Fluidized Bed Combustion

Deployed on Farms - Data on NOx + Plus NH3

BHSL NH_3 and NO_x Emissions

- Both NOx and NH3 emissions are low
- 0.9 % of total poultry litter N as NOx
- 0.1 % of total poultry litter N as NH3
- 8 % of nitrogen in ash + 1 % in emissions
- Total reduction of reactive nitrogen = 91%

NOx + NH3 = Reduced Reactive N

$$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$$

Required Temperature Range:
1,400 and 2,000 °F (760 and 1,090 °C)

Selective Non-Catalytic Reduction

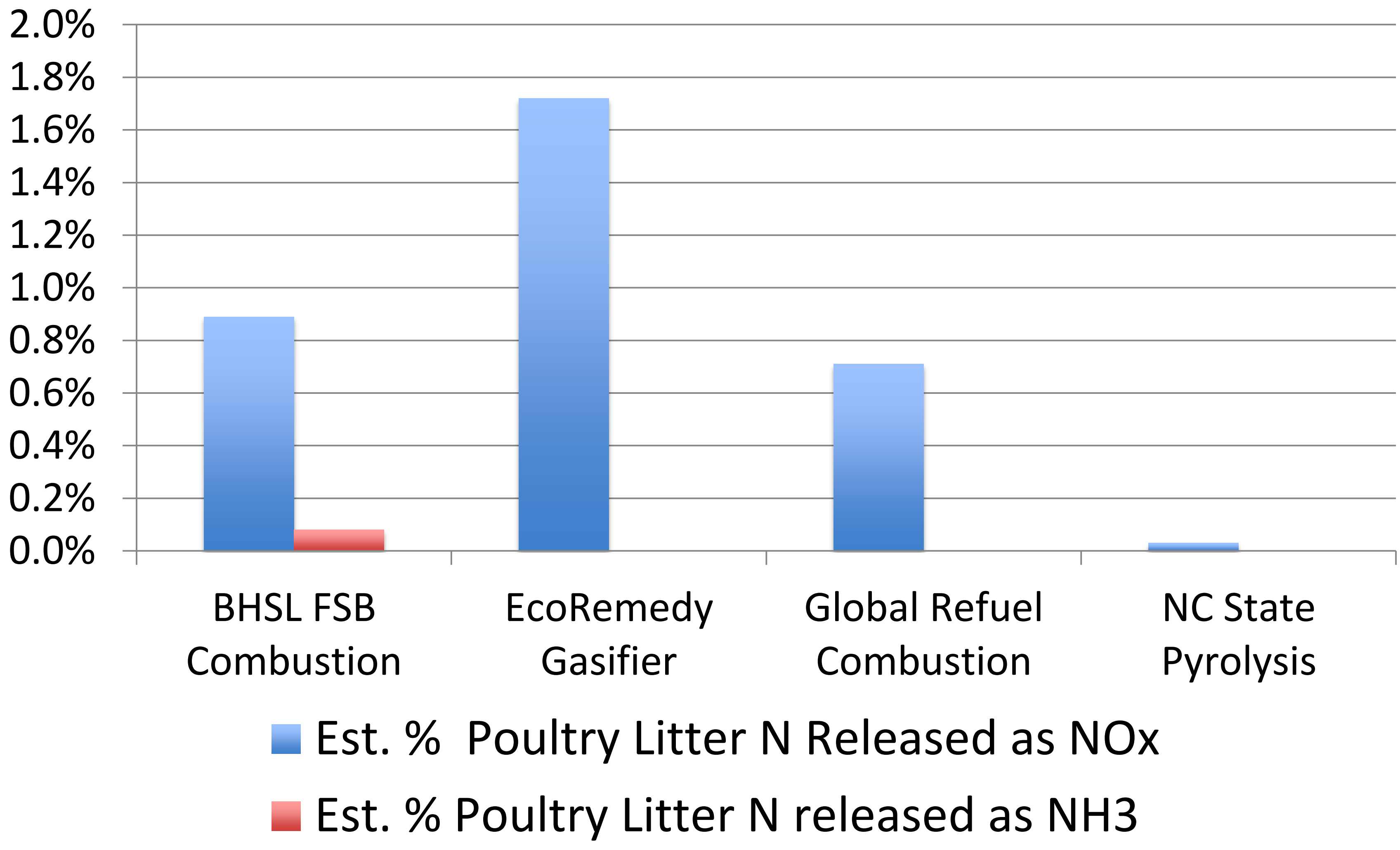
EcoRemedy ® Gasifier

Flintrock Farm
Lititz, PA

Global ReFuel, Combustion Demonstrated in VA, WV and PA

N.C. State Pyrolysis
Livestock and Poultry Waste Learning Cntr.

Reactive N in Emissions Compared to Reactive N in Poultry Litter Fuel



Reactive N Air Emissions:
Thermal Systems Compared to Land Application

	Thermal M2E N-NOx Emissions	Thermal M2E N-NH3 Emissions	Potential N-NH3 Emissions from Land-Application		
			10% Volatilization	50% Volatilization	90% Volatilization
	tons/year				
BHSL FSB Combustion	1.2	0.1	0.7	3.7	6.7
EcoRemedy Gasifier	2		0.7	3.7	6.7
Global Refuel Combustion	0.3		0.3	1.7	3.0
NC State Pyrolysis	0.01		0.8	4.2	7.5

Major Assumption: Assume all input poultry litter fuel has a N content of 3.5 percent.

Additional Considerations

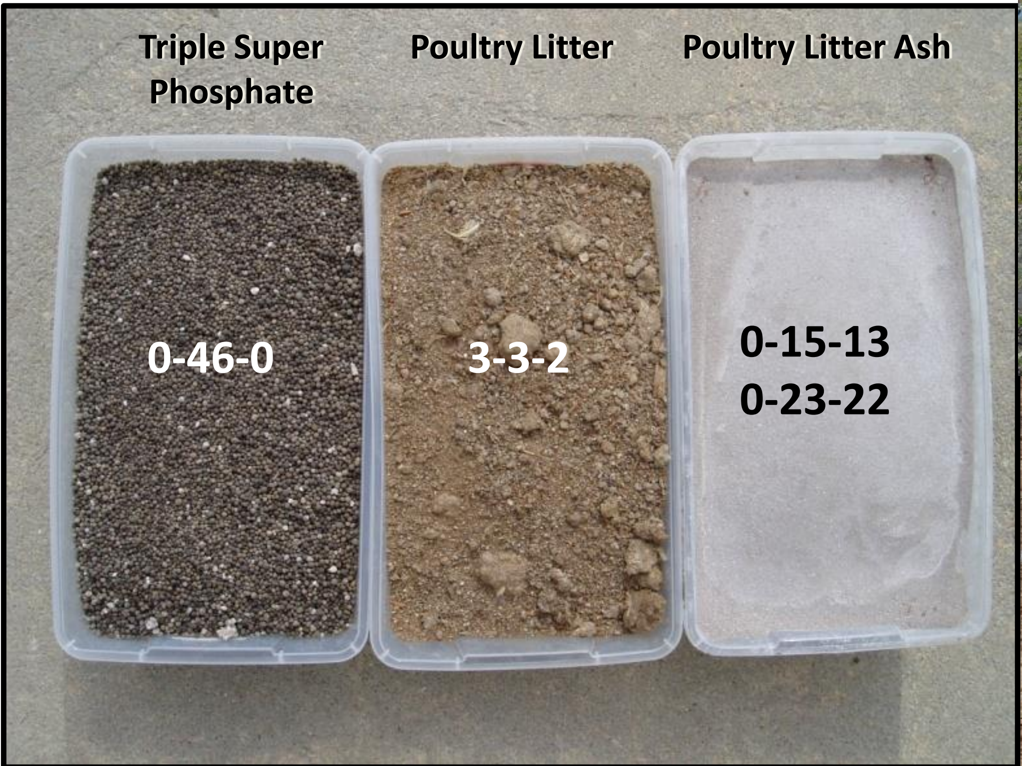
- Data on ammonia-nitrogen in air emissions is limited; more provided (spring/summer 2015) by Farm Manure-to-Energy Initiative

- Consider pre- and post-system scenarios for poultry litter and replacement fertilizer. For example…

Additional Considerations

- Prior land application? both rate and method (incorporated or injected vs. surface applied.
- Fertilizer replacement? Urea nitrogen has higher ammonia volatilization potential than Urea Ammonium Nitrate (UAN).
- Impact of increased adoption of mixed-species /legume cover crops to replace manure/fertlizer N?

Marketing Co-Products



Nutrient Concentration in Ash

Source	N (%)	$P2O_5$ (%)	K_2O (%)
Muriate of Potash (KCl)	0	0	60
Triple Super Phosphate (TSP)	0	46	0
Fresh Poultry Litter (typical value)	3.6	2.1	2.1
Ash, EcoRemedy ® Gasification (Broiler)	0.5	13.9	7.0
Ash, bhsl – Combustion (Broiler)	0.3	19.1	14.3
Ash, Blue Flame – Combustion (Broiler)	0.1	14.6	9.4
Ash, Global Refuel – Combustion (Broiler)	0.3	14.0	14.7
Ash, Global Refuel – Combustion (Turkey)	0.3	23.8	12.6
Biochar, NC State – Pyrolysis (Broiler)	1.4	5.2	1.9
Biochar, Coaltech, Frye Farm – Pyrolysis (Broiler)	2.5	5.9	5.5

Field Trial Results

- Ash and biochar P solubility ranges from 80 to 95%.

- Field trials indicate materials are suitable replacments for commercial P and K fertilizer.

  – In most cases, no statistical difference between P and K sources was demonstrated.

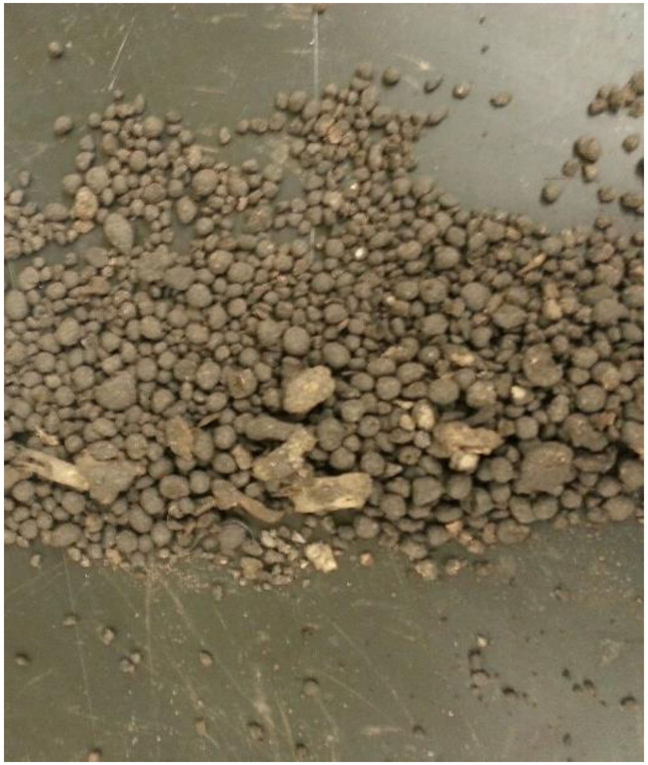
  – Not allowable for organic due to National Organic Protocol = high value market lost.

- Material handling is an issue – minimizing dust will be important (pelletizing, granulation, or using moisture to ensure appropriate application).

Material Handling

- Reluctant to add water.
  - Added weight at point of origin and added headache at-application.
- When making granules, urea was the best binder.
  - Water too weak.
  - No benefit to other binders.

Material Handling



- Demonstration material = Global Refuel turkey ash
- Urea binder = 9-11-5
- Urea binder + urea granules + potassium sulfate = 13-13-13
- Urea binder + N + K + denitrification inhibitor = 13-13-13 with nitrogen protection

Marketing Ash

- One vendor has established a market with soybean growers in the Midwest.

- Demonstrated willingness to pay market rates for P and K due to added micronutrients.

  – Sulfur, magnesium, calcium, etc. considered “free”

- Key markets will be growers (particularly soybean) without access to low cost manure or biosolid resources.

Marketing Ash

Ash value will decrease as energy prices decrease and inorganic fertilizers become cheaper to manufacture and transport.

- Prediction of <$42 for a barrel of oil = bad for ash price