Energy balance of pyrolyzing dairy manure

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PROJECT PARTNERS:

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Spruce Haven Farm
Union Springs, New York

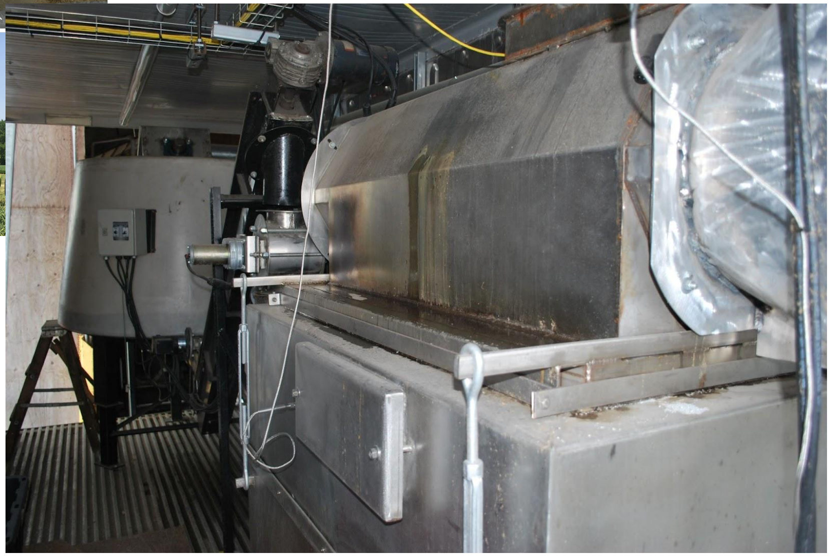
CFS Cuff Farm Services
Auburn, New York

BIOMASS CONTROLS PBC
Woodstock, Connecticut

nyserda Energy. Innovation. Solutions.

Project partners

- Spruce Haven
- NYSERDA
- Biomass Controls
- Cuff Farm Services



There are many challenges with managing manure

Herd size	Number of farms	Manure Spread (m^3 $farm^{-1}$ yr^{-1})	Cost for spreading (\$ $farm^{-1}$ yr^{-1})
1-9	844	44 to 396	$399 to $3,588
10-19	364	440 to 836	$3,987 to $7,576
20-49	1,131	880 to 2,156	$7,974 to $19,537
50-99	1,295	2,200 to 4,356	$19,936 to $39,473
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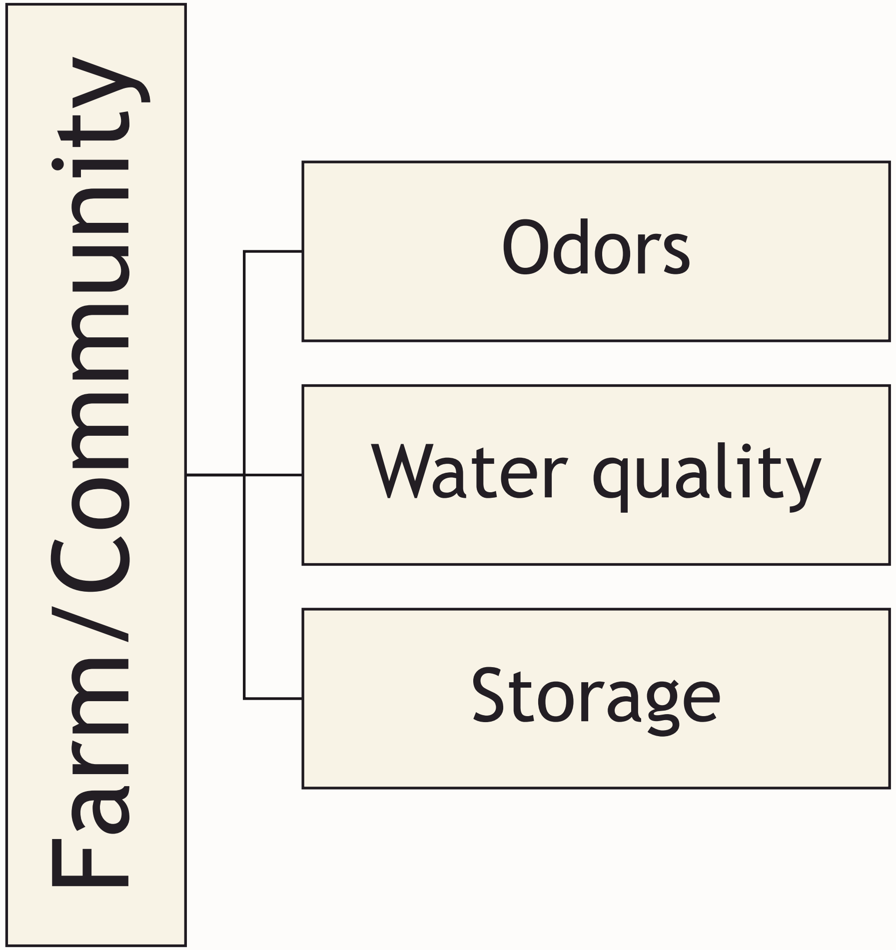
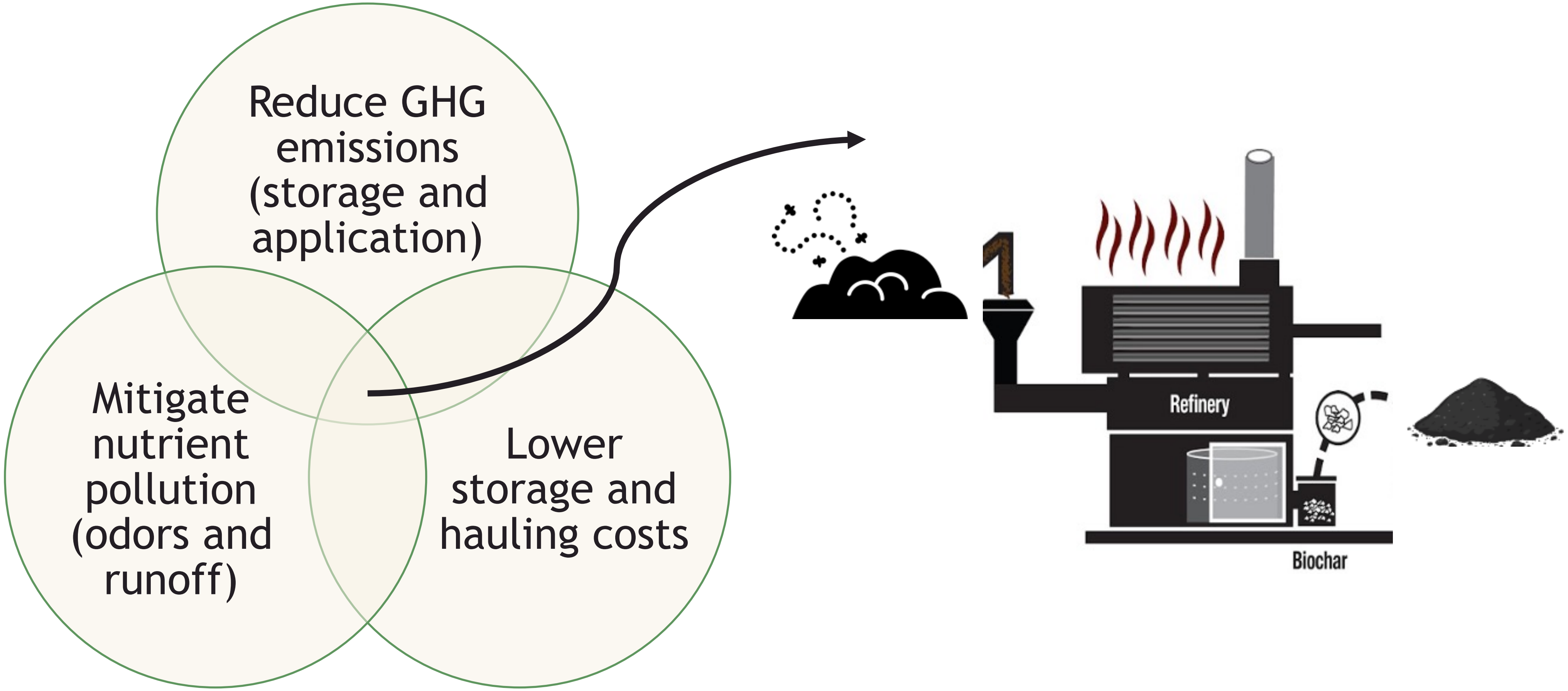
> 5,000	1	220,000 +	$1,993,600 +



Pyrolyzing manure can address many challenges of manure management



Our objective is to quantify the environmental and socioeconomic benefits of on-farm pyrolysis

- Perform an energy balance for drying and pyrolyzing manure
  - Quantify net energy
- Quantify environmental benefits
  - Reduction in GHG emissions from transport, storage, and application
  - Reduction in nutrient runoff and improvements in nutrient use efficiency
- Quantify socioeconomic benefits
  - Reduction in odors and easier storage options
  - Carbon crediting from manure biochar

Previous work suggests that there is sufficient energy in manure to pre-dry it

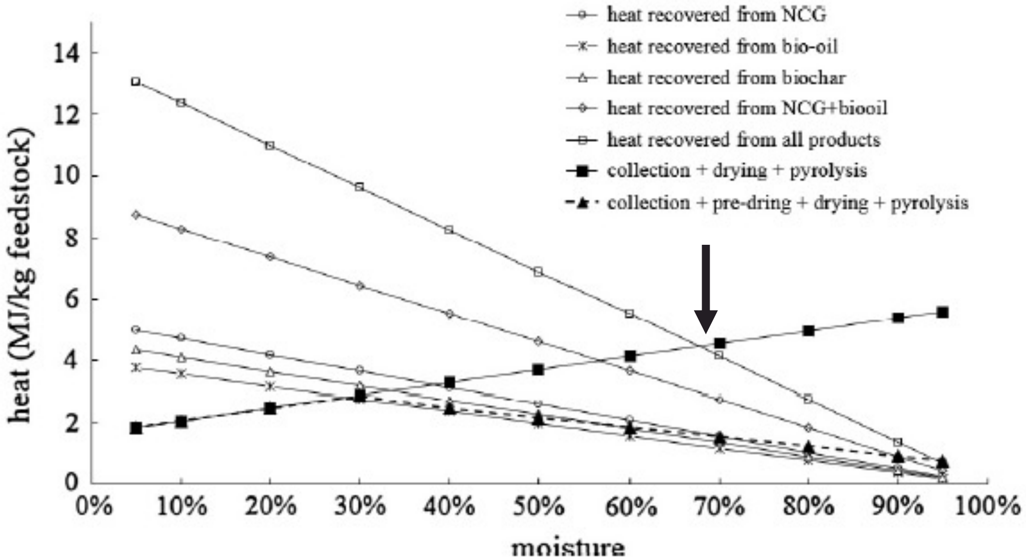
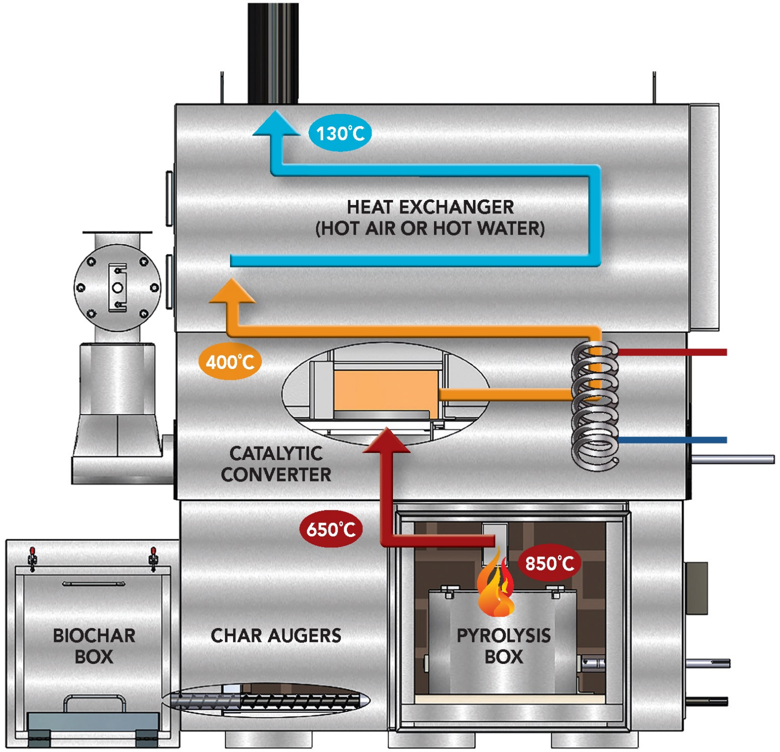


Fig. 6. Relationship between energy consumption and heat recovered during wet human manure pyrolytic process.

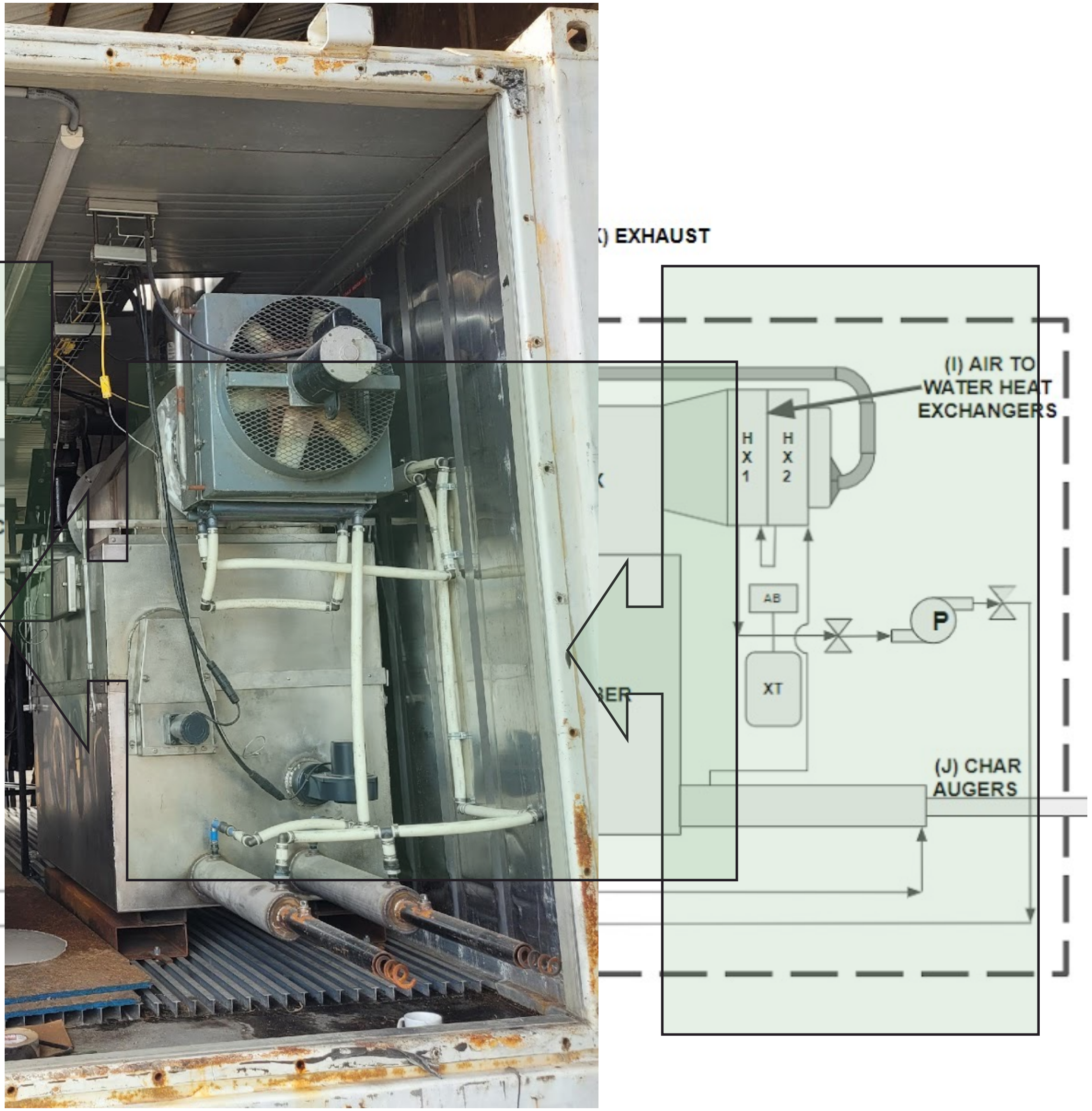
We performed an energy balance for an on-farm, integrated pre-drying pyrolysis system

The pyrolysis system was integrated with a hydronic drying system

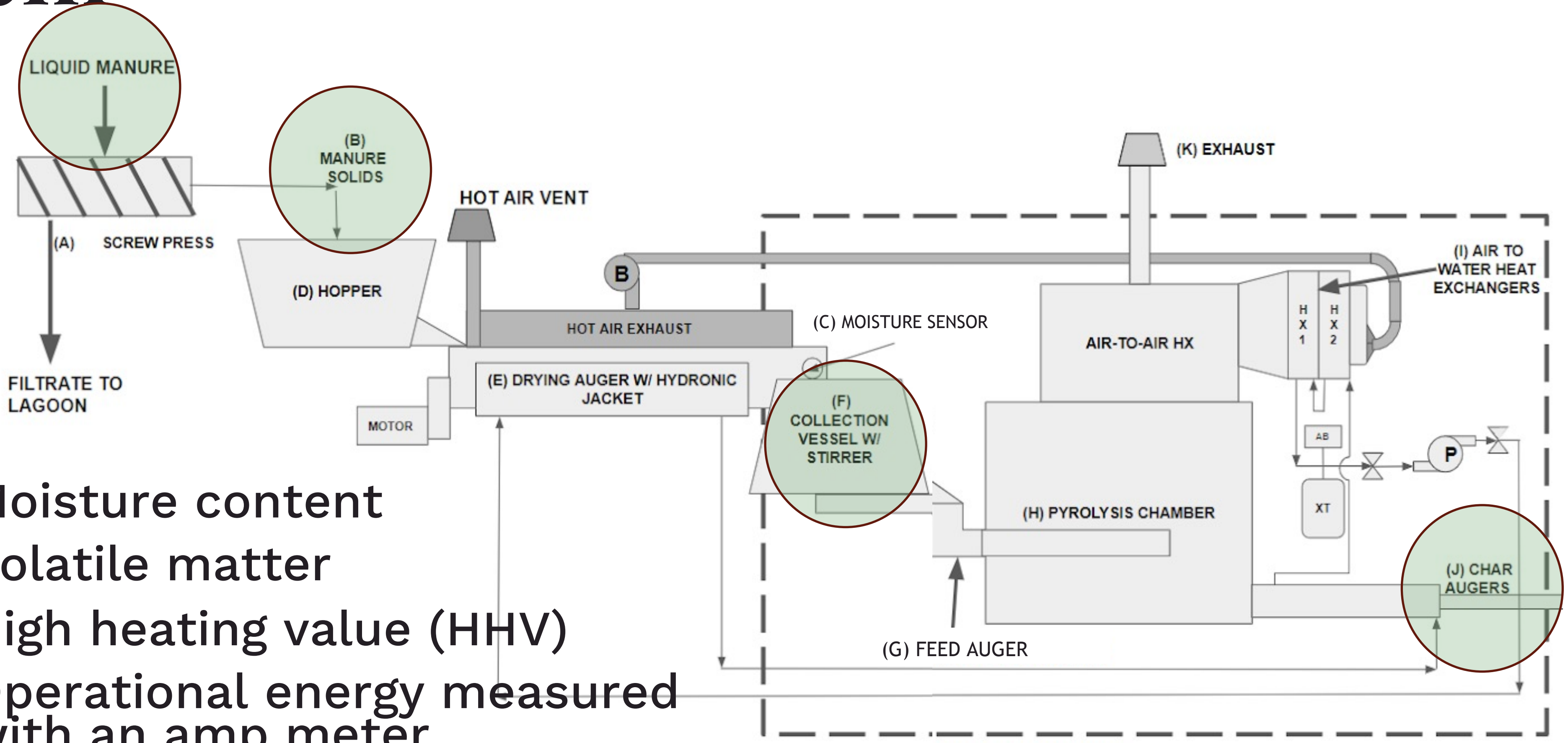
Hydronic drying system



- A dry feedstock is combusted to bring the pyrolysis box to the target temperature.
- Heat is transferred to a hydronic drying system via the heat exchanger.
- The heated hydronic system, which circulates hot water in a jacket around the feedstock, is used to dry incoming manure solids.
- Dried manure solids are fed into the pyrolysis box.
- The feedstock is rapidly converted to biochar.

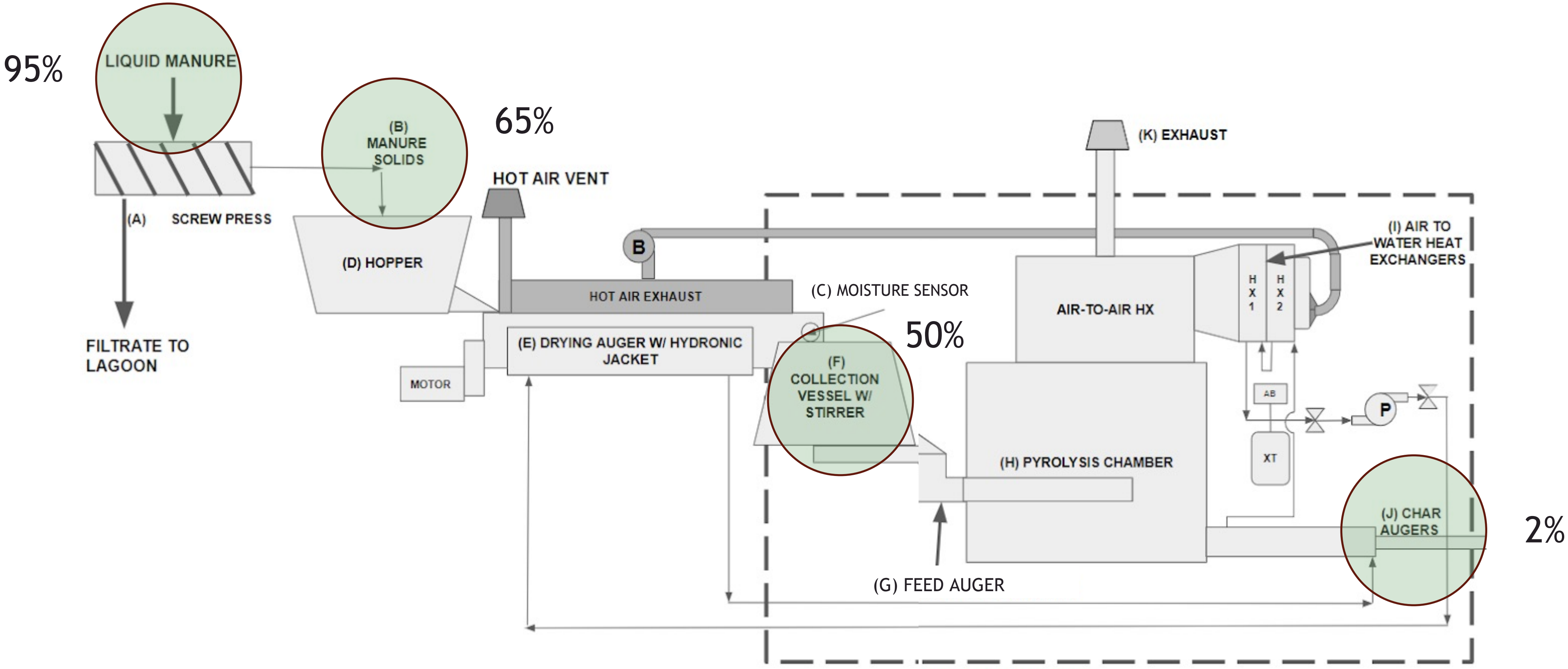

EXHAUST
(I) AIR TO
WATER HEAT
EXCHANGERS
HX1
HX2
AB
XT
P
(J) CHAR
AUGERS

Samples were collected throughout the system

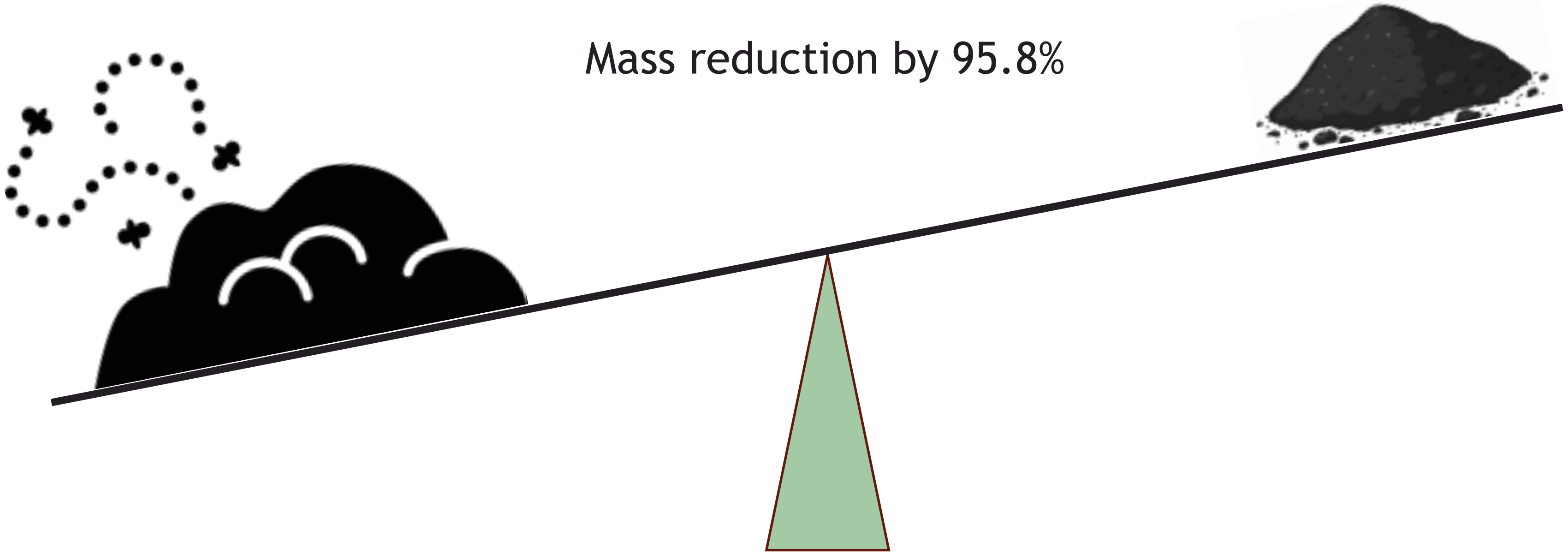


- Moisture content
- Volatile matter
- High heating value (HHV)
- Operational energy measured with an amp meter

We measured the moisture content throughout the system

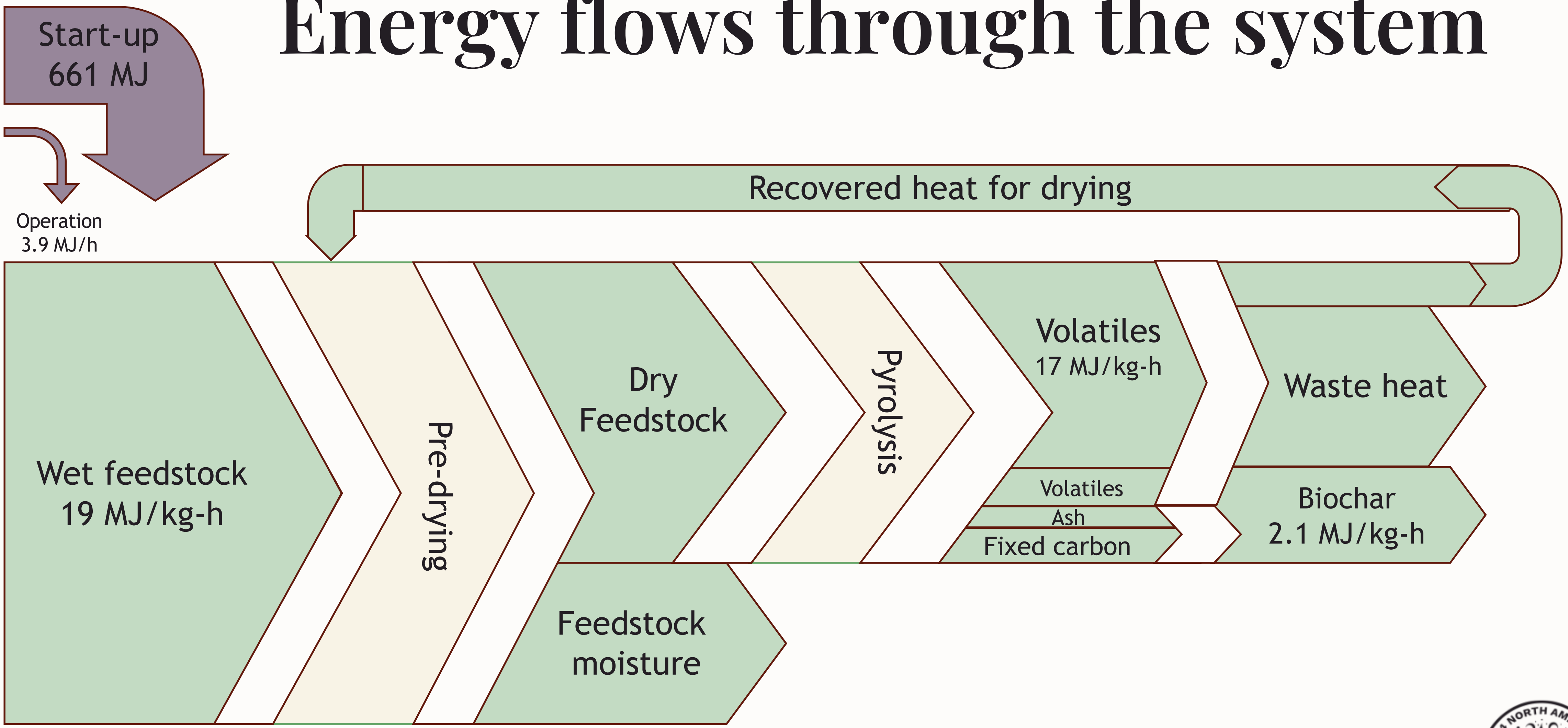


Pyrolysis reduces the mass and volume and manure

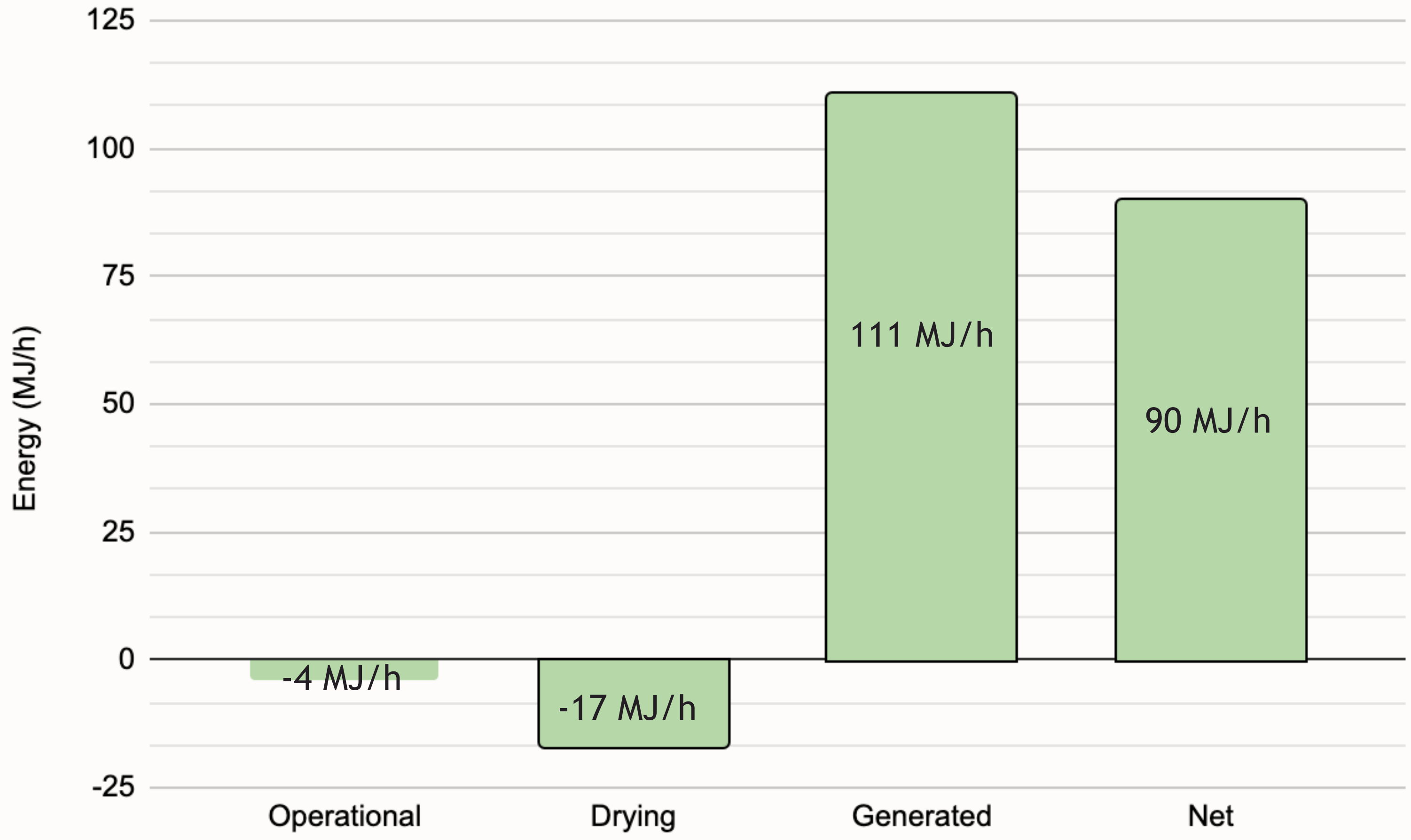


Volume reduction by 80.4%

Energy flows through the system



There is sufficient energy to pre-dry the manure solids in an integrated system



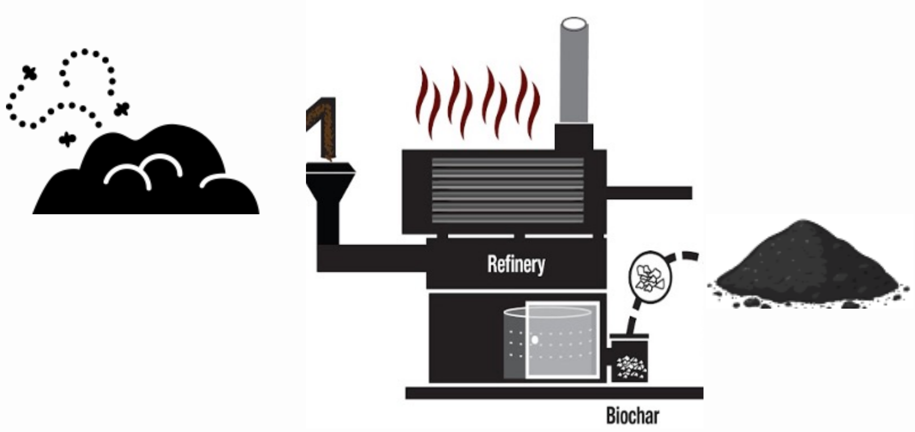
Next steps

- Upgrade the heat recovery system
  - Generate energy for the farm to heat manure before going into digester
- Determine the threshold moisture content for energy-neutral pyrolysis
- Test different local feedstocks
  - Model how an on-farm pyrolysis system can be used to serve local waste generators
- Conduct field trials with the manure biochar and evaluate its nutrient use efficiency

Conclusions

- Pyrolysis generates sufficient energy to pre-dry manure solids in an integrated drying system.
- Additional energy generated can be recovered from the system and redirected for other farm needs.
- On-farm pyrolysis can reduce mass and volume of dairy manure to lower storage and hauling costs.

Thank you!



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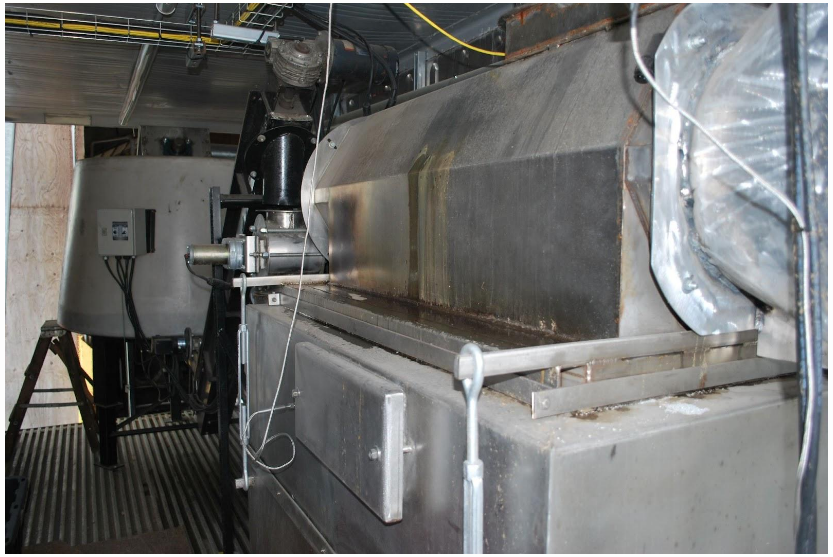

Appendix

- Spruce haven # of cows, kiln residence time, Biomass Controls design parameters
  - Biomass Controls – 200 cows, handle 50 kg/hr of wet mass input and 13 kg/h production
  - Kiln residence time of 30-115 mins depending on operation
  - Spruce Haven has 2000 cows, 3700 including calves and heifers, 2600 cow equivalent of manure
- Ash content and volatile content values + other BC characteristics according to IBI
  - 8% for manure solids and 26% for BC ash contents
  - 79% volatile for manure and 26% for BC volatiles
- Cost analysis
  - Spruce Haven can save ~$20,000 per 200 cows as compared to conventional manure management vs pyrolysis only for storing, hauling, spreading and BC application (does not include environmental benefits)
  - For 2600 cows of manure, as much as $2.5 million in savings

- In addition, energy production of anaerobic digestion increases by 42% when coupled with pyrolysis
- biochar can be applied as an amendment to composts and reduce about 50% nitrogen losses (Steiner et al., 2010; Awasthi et al., 2016) which constitutes an energy savings of about 0.9 MWh/ton of crop residue (at application rates of 20% w/w for 1 ton of dry compost with 2% N; 0.0091 MWh/kg N from Zhang et al., 2013). Alternatively, the biochar can be added to soil and reduce nitrogen losses by 82% (Guerena et al., 2013) which constitutes an energy saving from saved nitrogen fertilizer production equivalent to 0.75 MWh/t crop residue at application rates of 5 ton/ha once over a 10-year period
- New York State currently has 4000 dairy farms (Cuomo and Ball, 2017), 500 of which are dairy farms falling in the concentrated animal feeding operation categories of more than 300 or 700 cows.

Appendix

Source	Distance (km)	Time (min)	# Loads Spread	Total Costs (per load)	Total Annual Cost
Dairy experts	6 to 32	n/a	n/a	n/a	n/a
Howland & Karszes	10 to 32	23 to 53	72 to 923	$36 to $116	$2,592 to $107,068

- One cow on a NY dairy farm produces around 8,000 gallons of "manure" per year (this includes feces and urine as well as waste water, bedding material, sprinkler water, washdown water and other grey water).
- A study published in 2014[1] suggests that an average dairy farm spreads around 44,300 liters (or 11,700 gallons) of manure per cow per year.
- The daily distance travelled to transport manure varies depending on farm size, but ranges from about 2 to 16 kilometers one-way (Table 2).
- The average annual cost for manure hauling and spreading (including equipment , labor and fuel) is more than $200,000 per farm per year for farms with more than 500 cows[1]. Additionally, storage poses a cost to the farms.

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Sample ID: Manure Biochar 061319
Lab ID. Number: 9060926-01

International BioChar Initiative (IBI) Laboratory Tests for Certification Program

	Dry Basis Unless Stated:	Range	Units	Method
Moisture (time of analysis)	67.2		% wet wt.	ASTM D1762-84 (105c)
Bulk Density	15.7		lb/cu ft	
Organic Carbon	74.5		% of total dry mass	Dry Combust-ASTM D 4373
Hydrogen/Carbon (H:C)	0.43	0.7 Max	Molar Ratio	H dry combustion/C(above)
Total Ash	11.9		% of total dry mass	ASTM D-1762-84
Total Nitrogen	0.97		% of total dry mass	Dry Combustion
pH value	9.66		units	4.11USCC:dil. Rajkovich
Electrical Conductivity (EC20 w/w)	1.871		dS/m	4.10USCC:dil. Rajkovich
Liming (neut. Value as-CaCO3)	13.4		%CaCO3	AOAC 955.01
Carbonates (as-CaCO3)	5.0		%CaCO3	ASTM D 4373
Butane Act.	2.1		g/100g dry	ASTM D 5742-95
Surface Area Correlation	200		m2/g dry	G

All units mg/kg dry unless stated:

		Results	Range of Max. Levels	Reporting Limit (ppm)	Method
Arsenic	(As)	**ND**	13 to 100	0.38	J
Cadmium	(Cd)	**ND**	1.4 to 39	0.15	J
Chromium	(Cr)	54.1	93 to 1200	0.38	J
Cobalt	(Co)	3.1	34 to 100	0.38	J
Copper	(Cu)	152	143 to 6000	0.38	J
Lead	(Pb)	0.7	121 to 300	0.15	J
Molybdenum	(Mo)	1.4	5 to 75	0.38	J
Mercury	(Hg)	**ND**	1 to 17	0.000	EPA 7471
Nickel	(Ni)	80.1	47 to 420	0.38	J
Selenium	(Se)	**ND**	2 to 200	0.76	J
Zinc	(Zn)	60.0	416 to 7400	0.76	J
Boron	(B)	30.0	Declaration	3.78	TMECC
Chlorine	(Cl)	2498	Declaration	20.0	TMECC
Sodium	(Na)	1762	Declaration	377.7	E
Iron	(Fe)	3833	Declaration	18.9	E
Manganese	(Mn)	720	Declaration	0.38	J

Particle Size Distribution

	Results	Units	Method
< 0.5mm	35.3	percent	F
0.5-1mm	22.8	percent	F
1-2mm	22.0	percent	F
2-4mm	18.1	percent	F
4-8mm	1.8	percent	F
8-16mm	0.0	percent	F
16-25mm	0.0	percent	F
25-50mm	0.0	percent	F
>50mm	0.0	percent	F

Basic Soil Enhancement Properties

	Results	Units	Method
Total (K)	7021	mg/kg	E
Total (P)	2242	mg/kg	E
Ammonia (NH4-N)	21.2	mg/kg	A
Nitrate (NO3-N)	0.7	mg/kg	A
Organic (Org-N)	9659	mg/kg	Calc.
Volatile Matter	18.8	percent dw	D

* "ND" stands for "not detected" which means the result is below the reporting limit.

Method A Rayment & Higginson
D ASTM D1762-84
E EPA3050B/EPA 6010
F ASTM D 2862 Granular
G Butane Activity Surface Area Correlation Based on McLaughlin, Shields, Jagiello, & Thiele's 2012 paper: Analytical Options for Biochar Adsorption and Surface Area
J EPA3050B/EPA 6020