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# Shifting Waste as a resource the paradigm:

Thomas Trabold
Associate Professor and Department Head
Golisano Institute for Sustainability
Rochester Institute of Technology

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## *Golisano Institute for Sustainability (GIS)*

Inter-disciplinary graduate program:

- M.S. Sustainable Systems
- M. Architecture
- Ph.D. Sustainability

- 4 research thrusts
  - ➢ Sustainable energy
  - ➢ Sustainable mobility
  - ➢ Sustainable production
  - ➢ Eco-IT

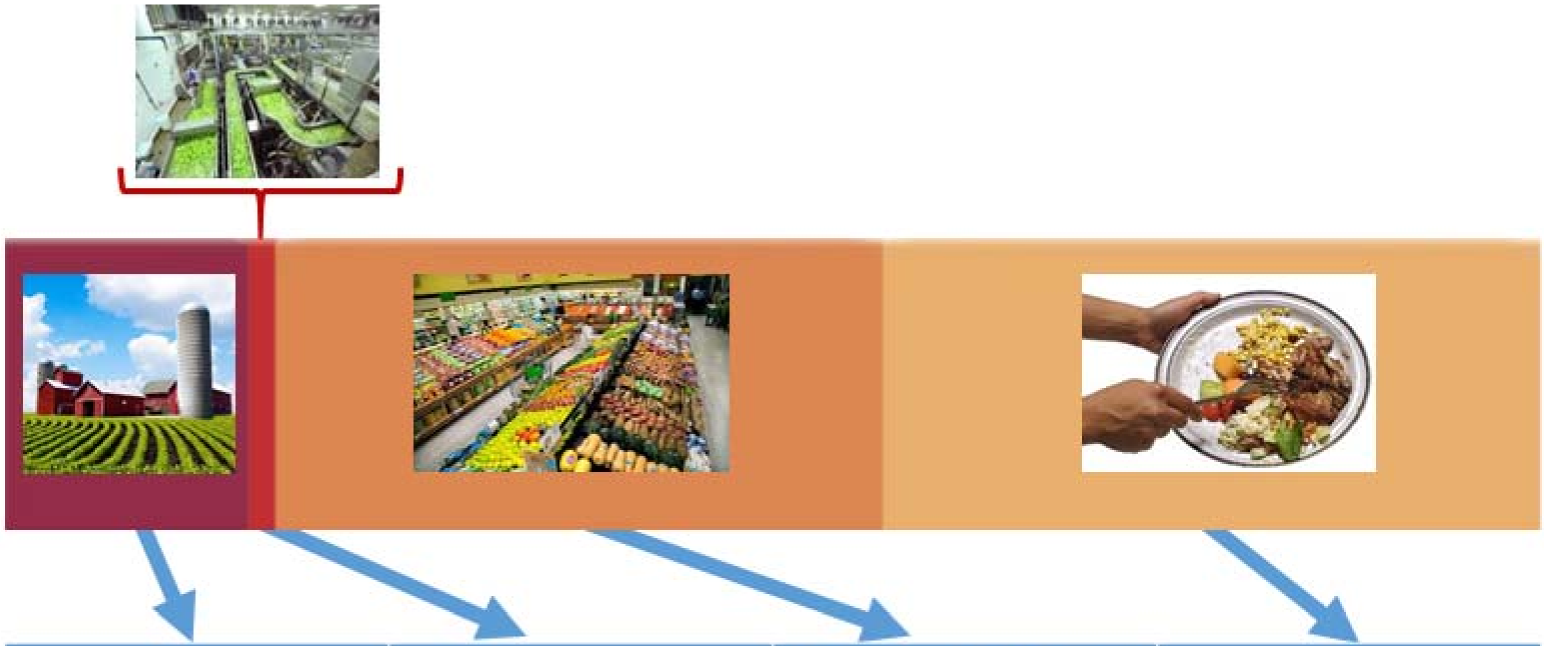
Also houses the New York State Pollution Prevention Institute (NYSP2I)

# *Conventional food waste management*

*Materials with significant potential value are treated by expending (fossil) energy to render them “harmless”.*

*How do we shift the paradigm from* ***food waste*** *to* ***food resource****?*

# *Food waste in the U.S. (2016)*



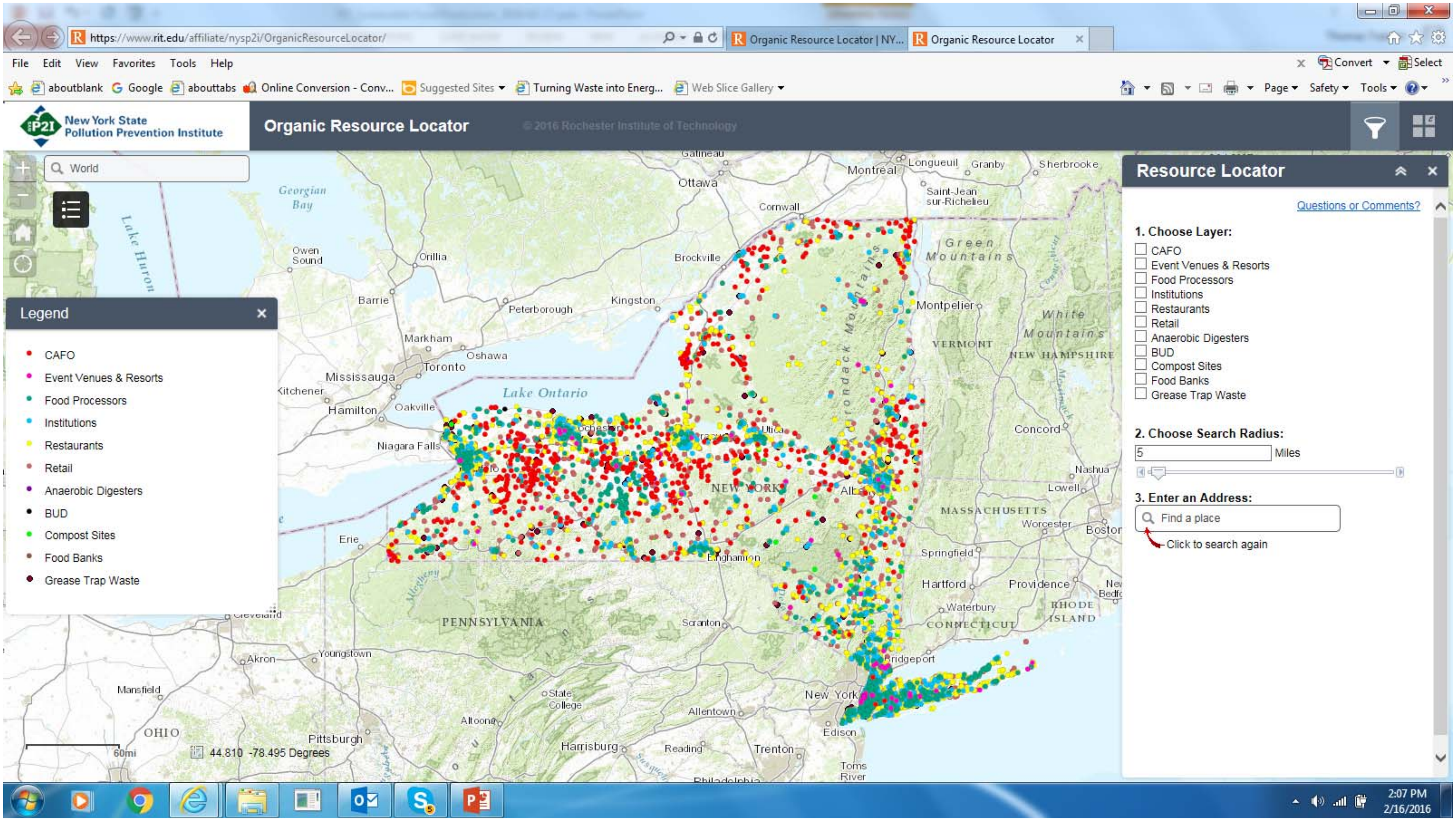
| | Agriculture | Food Processing | Consumer-Facing Businesses | Households |
|---|---|---|---|---|
| Food waste (million tons) | 10 | 1 | 25 | 27 |
| % of total waste | 16 | 2 | 40 | 43 |
| Cost of waste (billion $) | 15 | 2 | 57 | 144 |
| % of total cost | 7 | 1 | 26 | 66 |

ReFED, Rethink Food Waste through Economics and Data, 2016. *A Roadmap to Reduce U.S. Food Waste by 20 Percent*.

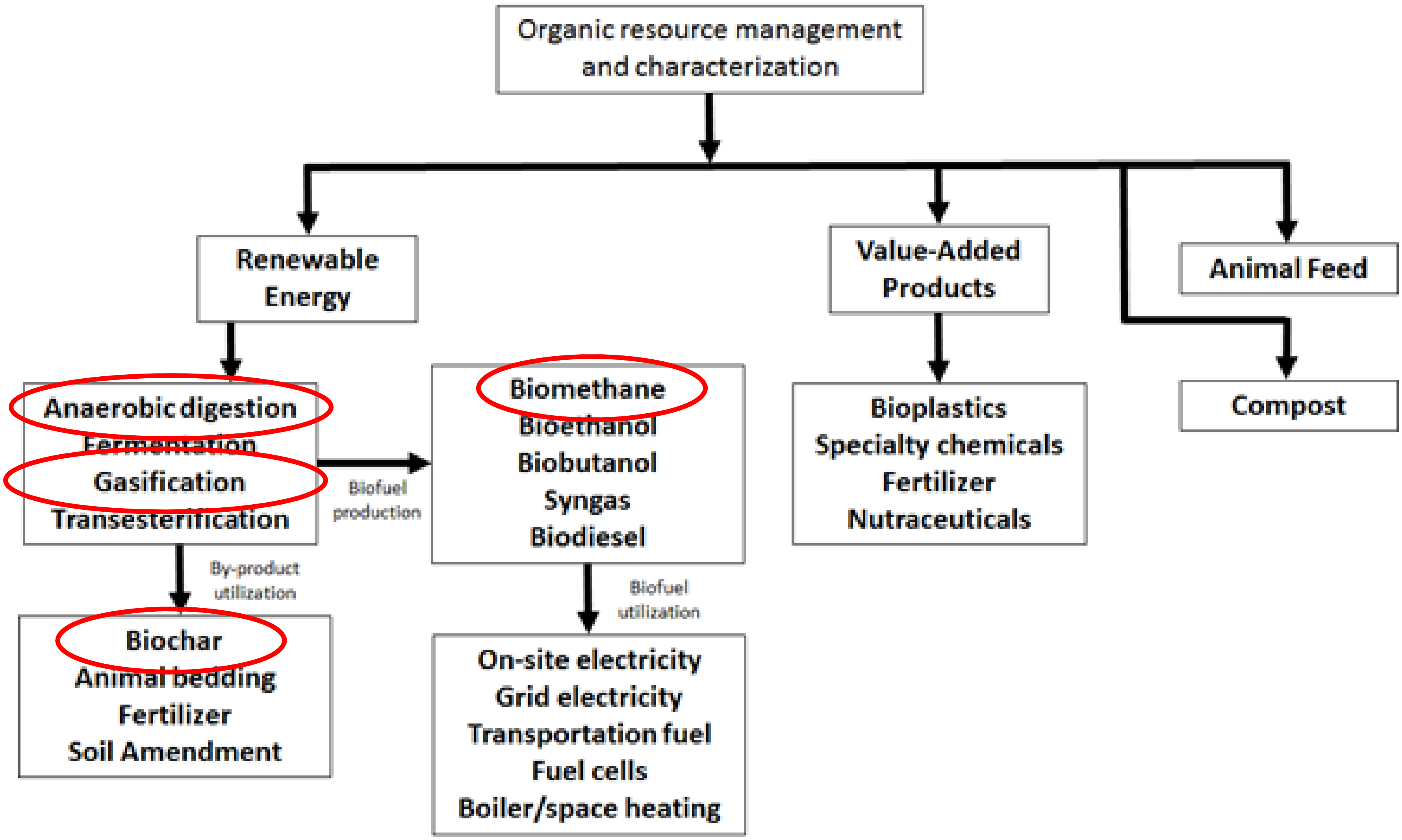
# Food waste in New York State

Organic Resource Locator (ORL) developed at RIT

https://www.rit.edu/affiliate/nysp2i/organic_resource_locator#



# Food waste utilization pathways



# *Renewable energy via anaerobic digestion*

Farm-based system that produces biogas (~60% $CH_4$) from manure-food waste co-digestion (70:30 ratio)

71% reduction in net GHGs, mostly from displacing grid electricity and inorganic fertilizers

Challenges

- What to do with the digestate, especially if not on a farm?
- What's the best use of biogas?

J.H. Ebner, M.J. Rankin, J. Pronto, R. Labatut, C. Gooch, A.A. Williamson and T.A. Trabold, "Greenhouse gas emissions analysis of a commercial-scale anaerobic co-digestion plant processing dairy manure and food waste," *Environmental Science and Technology*, Vol. 49, 11199-11208 (2015).

# *Is thermochemical conversion an option?*

Heating at 300 – 1000°C with less than stoichiometric level of $O_2$ needed for full combustion

Advantages

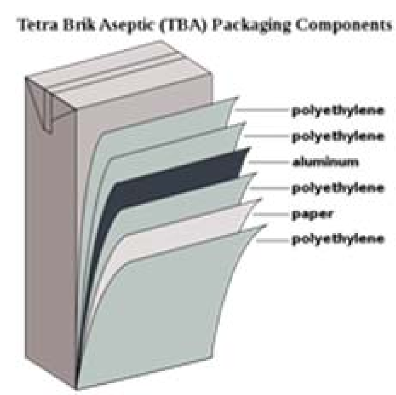
- Short residence time, relatively small systems
- Resilient to feedstock variability
- Significant volume/mass reduction
- “Biochar” and other co-products have many potential uses
- Carbon sequestration

Disadvantages

- May not be suitable for high moisture content wastes
- Relative value of co-products is not well understood
- Policymakers often confuse with combustion/incineration

# *Biochar from cafeteria food waste*

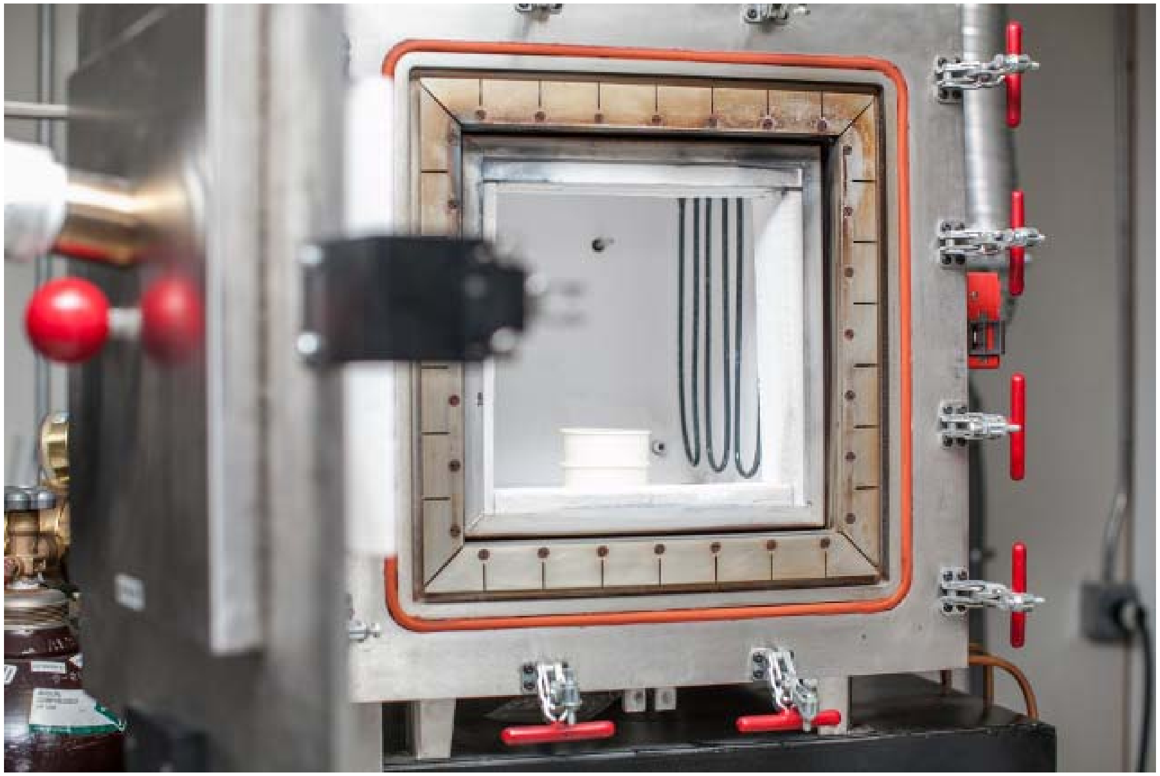

- Cafeteria lunch waste generated by 841 3rd to 5th grade students was collected, sorted and weighed on a daily basis from Sept 2017 to June 2018
- Compost: food waste, used paper napkins and Popsicle sticks.
- Recyclable materials: cans and plastic bottles marked with identification code triangle.
- Landfill waste: composed of plastic eating utensils, Tetrapak containers and various chip and snack bags made from metalized polypropylene.



# *Lab-scale: biochar from cafeteria food waste*

Material not recycled was comprised of 87% compostable waste and 13% of materials that would normally go to landfill.

What happens if food waste only and mixed waste are pyrolyzed in an $N_2$ environment at 1000ºC for 30 minutes?



# *Lab-scale: biochar results*

Control Laboratories
42 Hangar Way
Watsonville, CA 95076
www.biocharlab.com
Tel: 831 724-5422
Fax: 831 724-3188

## Pure food waste

| All units mg/kg dry unless stated: | | Results | Range of Max. Levels | Reporting Limit (ppm) | Method |
|---|---|---|---|---|---|
| Arsenic | (As) | **ND** | 13 to 100 | 0.68 | J |
| Cadmium | (Cd) | **ND** | 1.4 to 39 | 0.27 | J |
| Chromium | (Cr) | 1.6 | 93 to 1200 | 0.68 | J |
| Cobalt | (Co) | **ND** | 34 to 100 | 0.68 | J |
| Copper | (Cu) | 1.5 | 143 to 6000 | 0.68 | J |
| Lead | (Pb) | **ND** | 121 to 300 | 0.27 | J |
| Molybdenum | (Mo) | 0.8 | 5 to 75 | 0.68 | J |
| Mercury | (Hg) | **ND** | 1 to 17 | 0.001 | EPA 7471 |
| Nickel | (Ni) | **ND** | 47 to 420 | 0.68 | J |
| Selenium | (Se) | **ND** | 2 to 200 | 1.36 | J |
| Zinc | (Zn) | 43.1 | 416 to 7400 | 1.36 | J |
| Boron | (B) | 7.6 | Declaration | 6.78 | TMECC |
| Chlorine | (Cl) | 501 | Declaration | 20.0 | TMECC |
| Sodium | (Na) | 5682 | Declaration | 677.7 | E |
| Iron | (Fe) | 54 | Declaration | 33.9 | E |
| Manganese | (Mn) | 4 | Declaration | 0.68 | J |

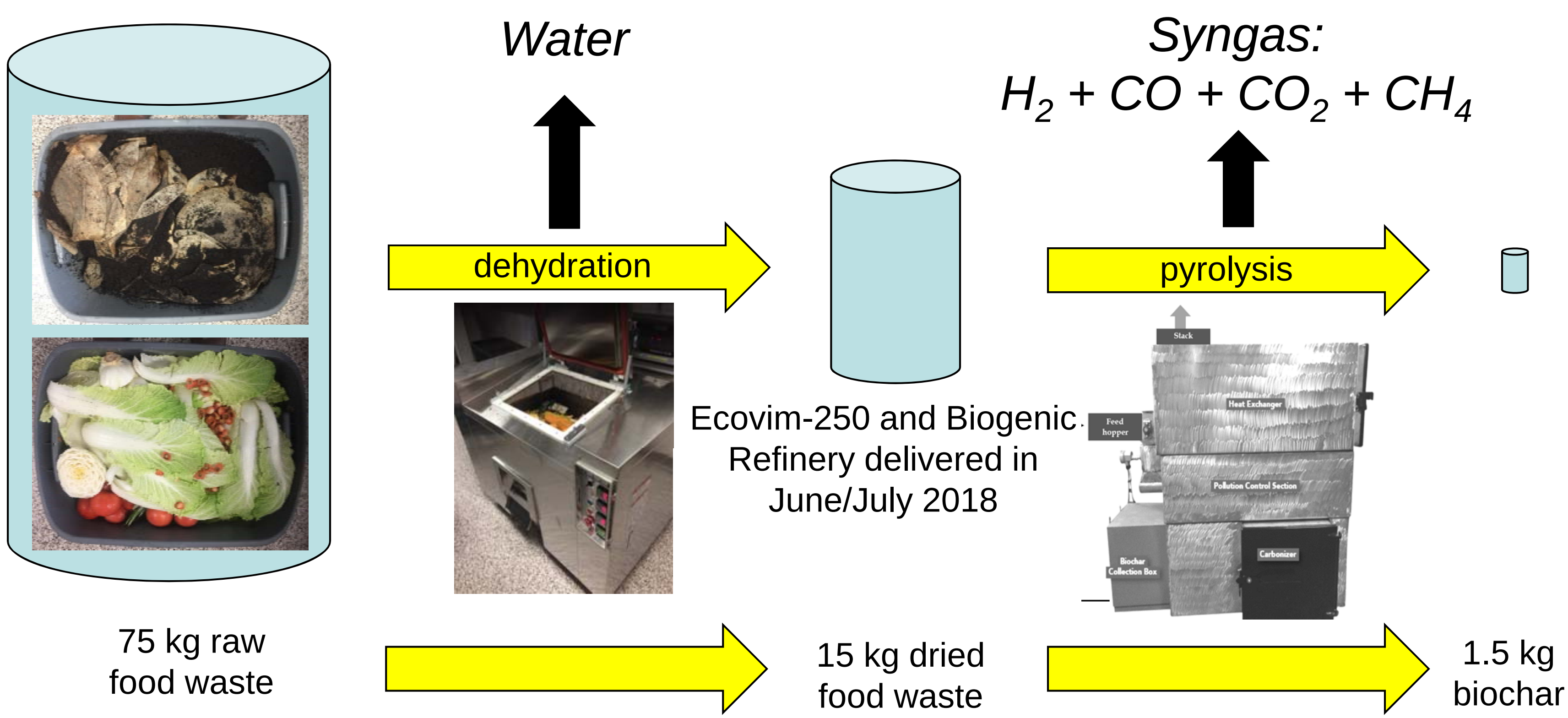
## Mixed waste

| All units mg/kg dry unless stated: | | Results | Range of Max. Levels | Reporting Limit (ppm) | Method |
|---|---|---|---|---|---|
| Arsenic | (As) | **ND** | 13 to 100 | 0.67 | J |
| Cadmium | (Cd) | **ND** | 1.4 to 39 | 0.27 | J |
| Chromium | (Cr) | 1.5 | 93 to 1200 | 0.67 | J |
| Cobalt | (Co) | **ND** | 34 to 100 | 0.67 | J |
| Copper | (Cu) | 13.4 | 143 to 6000 | 0.67 | J |
| Lead | (Pb) | **ND** | 121 to 300 | 0.27 | J |
| Molybdenum | (Mo) | 4.2 | 5 to 75 | 0.67 | J |
| Mercury | (Hg) | **ND** | 1 to 17 | 0.001 | EPA 7471 |
| Nickel | (Ni) | 1.9 | 47 to 420 | 0.67 | J |
| Selenium | (Se) | **ND** | 2 to 200 | 1.33 | J |
| Zinc | (Zn) | 10.3 | 416 to 7400 | 1.33 | J |
| Boron | (B) | 7.0 | Declaration | 6.65 | TMECC |
| Chlorine | (Cl) | 3855 | Declaration | 20.0 | TMECC |
| Sodium | (Na) | 5890 | Declaration | 665.3 | E |
| Iron | (Fe) | 250 | Declaration | 33.3 | E |
| Manganese | (Mn) | 6 | Declaration | 0.67 | J |

- Both pure food and mixed wastes had high organic carbon, low H:C, pH > 10 and [Na] > 5600 ppm
- Significant differences were observed only in chlorine (501 vs. 3855 ppm) and iron (54 vs. 250 ppm)
- Need simultaneous syngas analysis to determine fate of non-food constituents in co-pyrolysis of “real” post-consumer waste

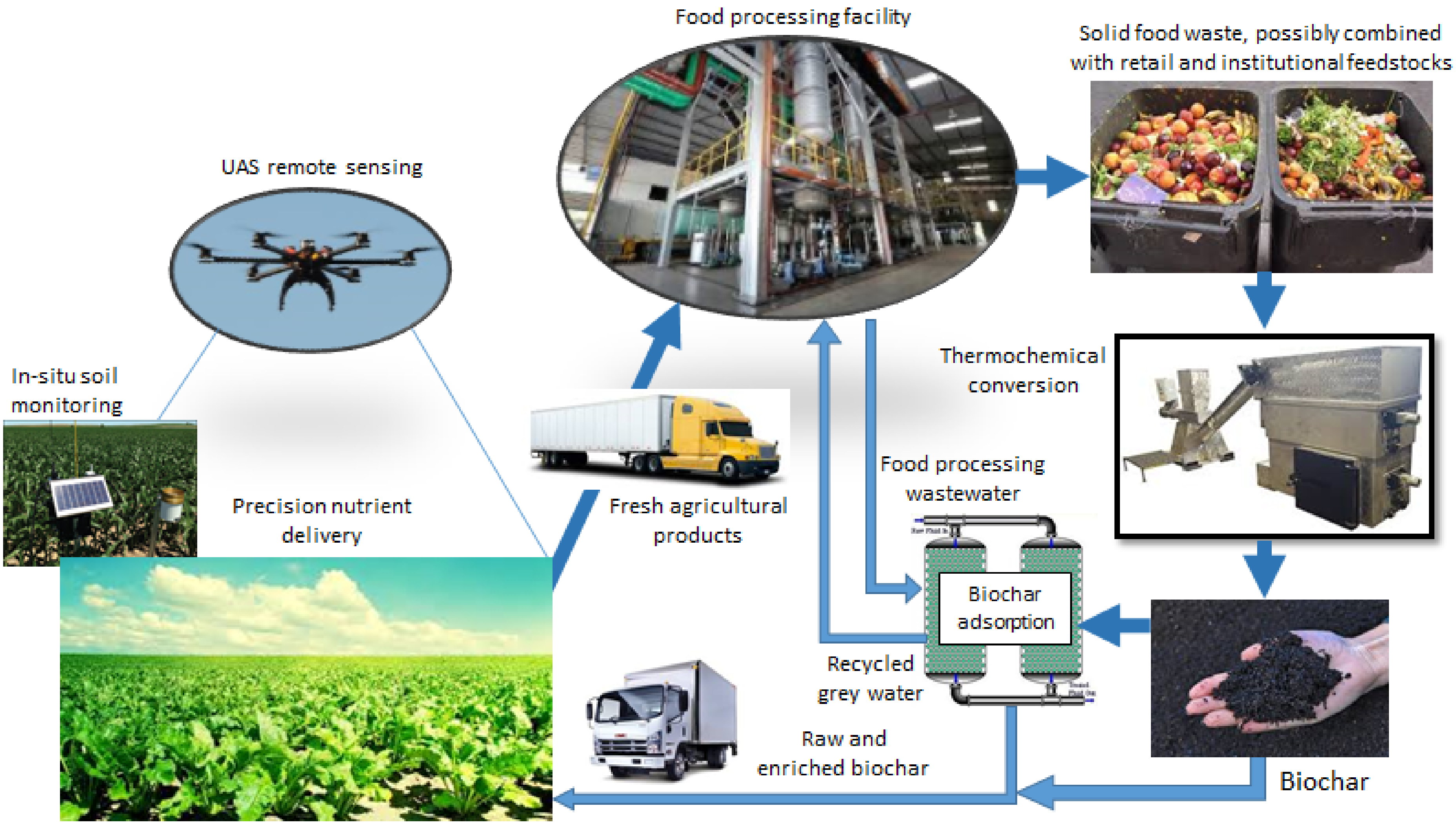
# *Applying thermochemical processes at scale*

- Short residence time may make physical size of system suitable for deployment at a single large generator
- Can process mixed waste: food + paper + plastic packaging
- Solid output (biochar) is shelf-stable for long term
- Significant mass reduction (up to 98%!)



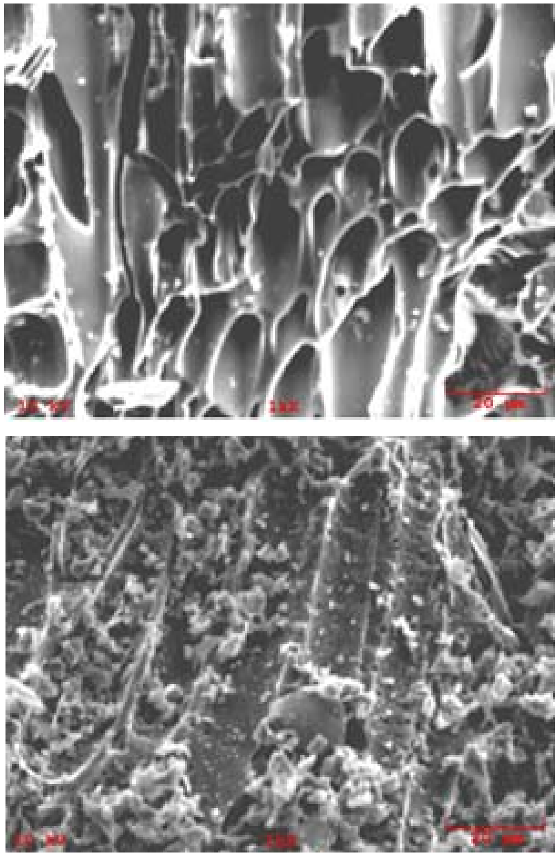
# Biorefinery - Concept #1

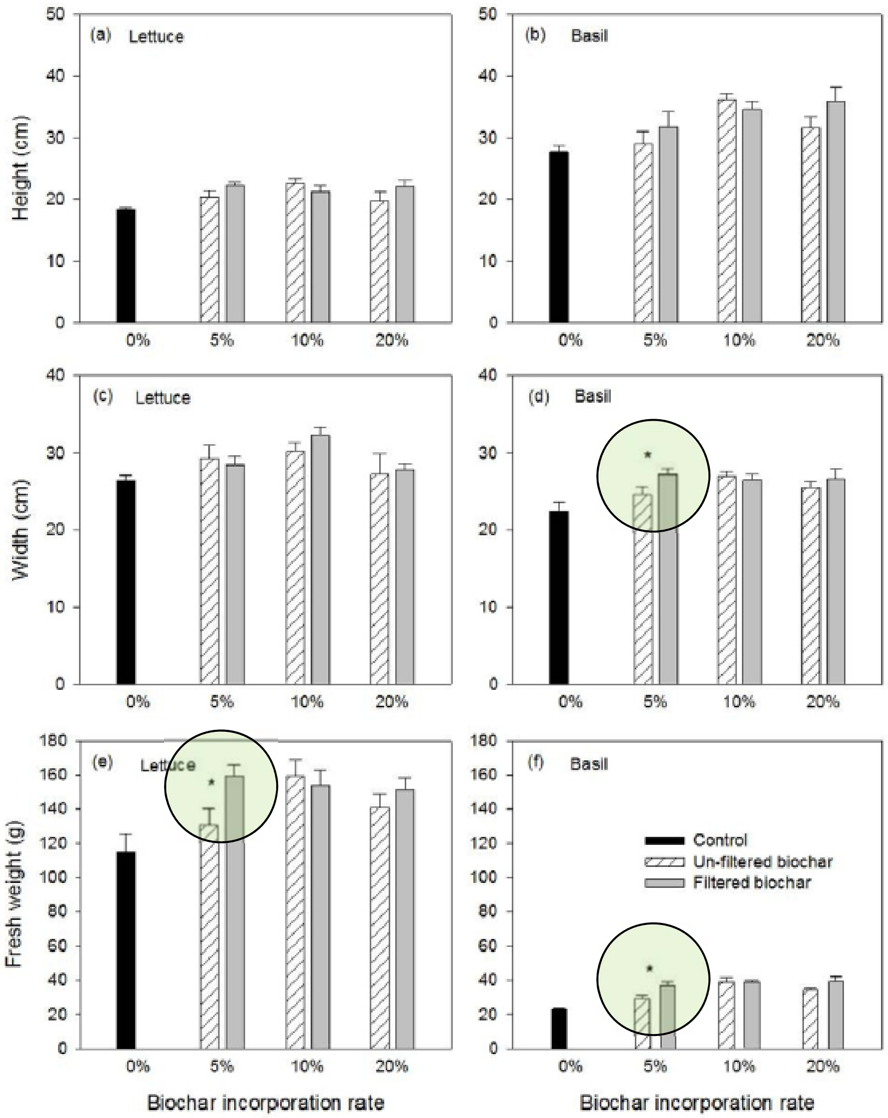
*Use biochar to return nutrients in food waste to the farm*



# Potential benefits of "enriched" biochar

Raw maple wood biochar, and "enriched" with tofu wastewater

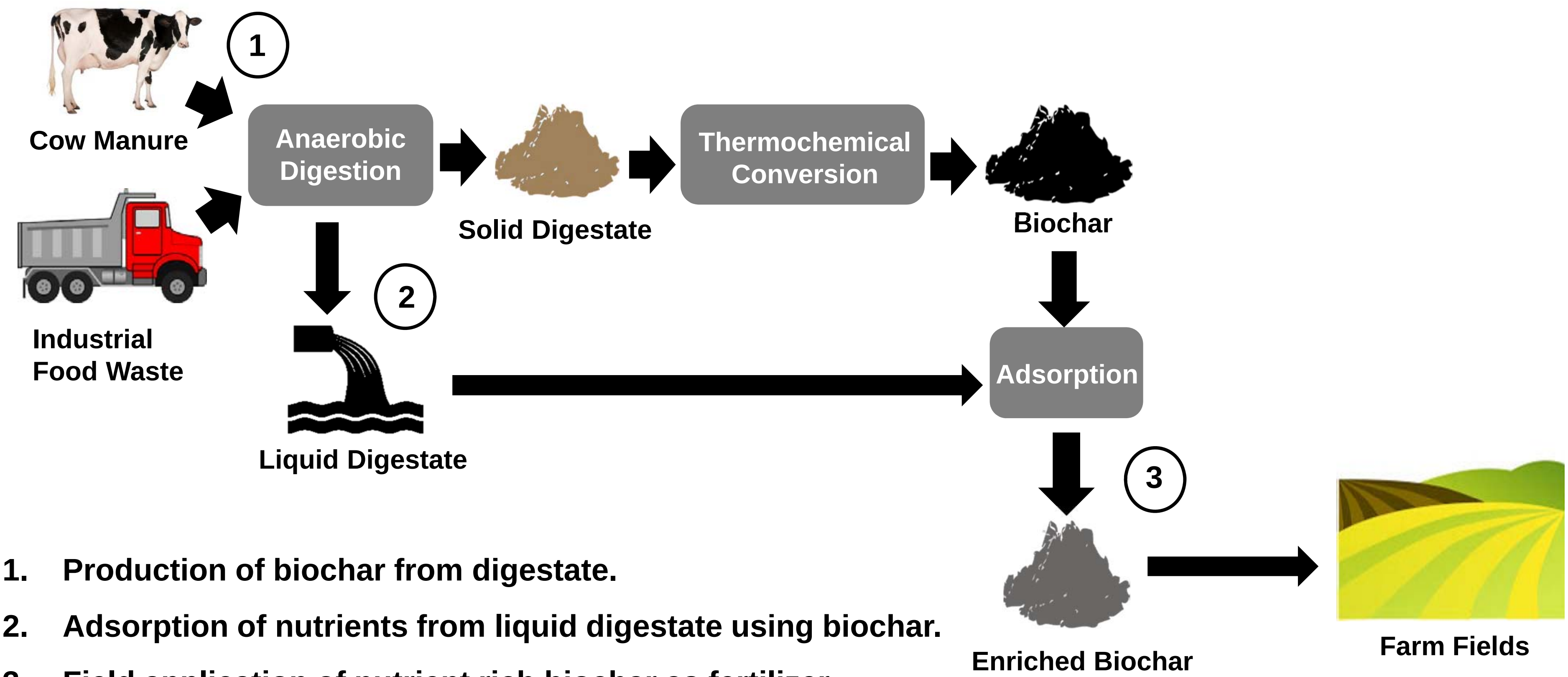





S. Barber, J. Yin, K. Draper and T.A. Trabold, "Closing nutrient cycles with biochar - from filtration to fertilizer," *Journal of Cleaner Production*, Vol. 197, 1597-1606 (2018).

# Biorefinery – Concept #2

*Use biochar to minimize environmental impact of effluent from anaerobic digestion*




1. **Production of biochar from digestate.**
2. **Adsorption of nutrients from liquid digestate using biochar.**
3. **Field application of nutrient rich biochar as fertilizer.**

# *Non-agricultural applications: magnetic biochar*

Unintended outcome resulted from two factors: high concentration of iron in digestate and Biomass Controls system architecture that enables controlled air flow

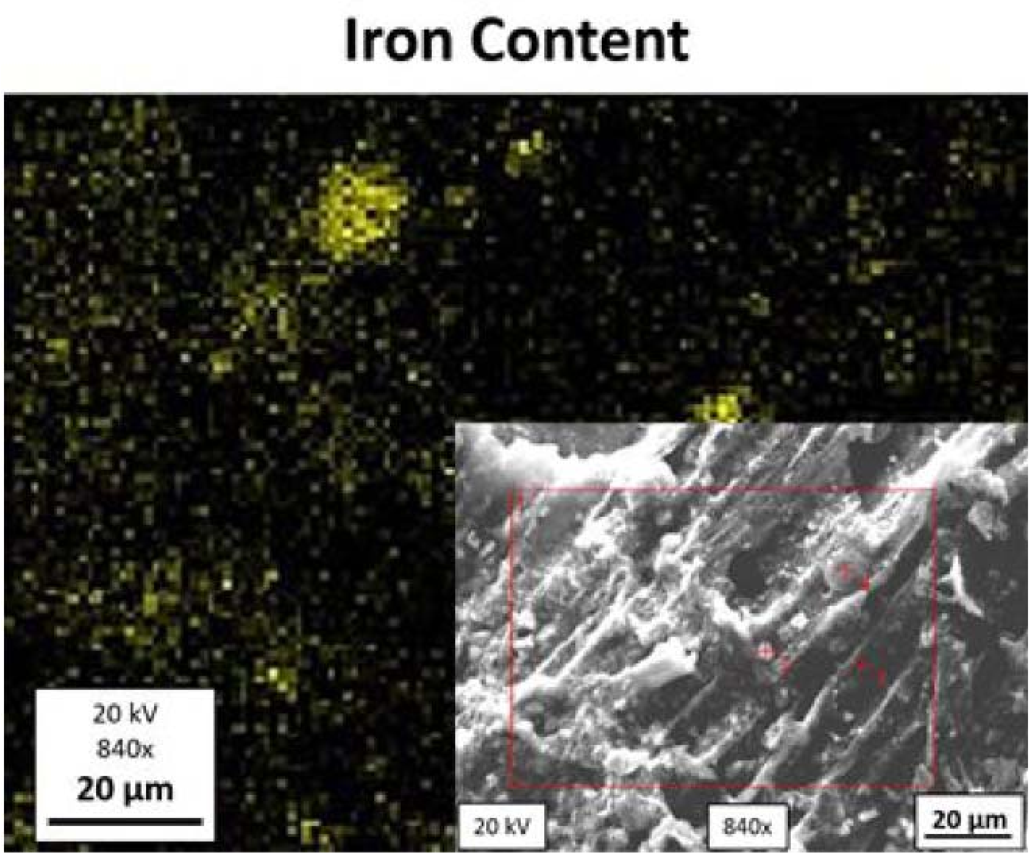



Table 1. Physical and chemical characteristics of digestate biochar.

| Measured parameter | Range (n=5) |
|---|---|
| Moisture, % | 3.3 – 5.5 |
| Ash, % | 19.3 – 27.4 |
| Volatile matter, % | 16.9 – 19.63 |
| Organic C, % | 47.2 – 61.6 |
| Surface Area, $m^2/g$ | 87 – 177.6 |
| Sat. Magnetization., emu/g (n=8) | 0.7 – 6 |

No need for precursor such as $FeCl_3$ to achieve formation of magnetite ($Fe_3O_4$)

Applications in wastewater treatment & supercapacitors

D. Rodriguez Alberto, K.S. Repa , S. Hegde, C.W. Miller and T.A. Trabold, “Novel production of magnetite particles via thermochemical processing of digestate from manure and food waste,” presented *at Joint MMM-Intermag Conference*, Washington, D.C., January 2019.

# *Conclusions and path forward*

- Best opportunities are in mixed pre- and post-consumer wastes where limited valorization options exist (“free” feedstock!)
- Need demonstrations at scale, with thermal integration to minimize impact of drying energy
- Seek out opportunities for biorefinery deployment with combined technologies that enhance sustainability
- Consider all available biomass feedstocks, especially those where constraints to conventional disposal practices are on the horizon (e.g., WWTP biosolids, packaged food)

Economic viability will be achievable only through consideration of all co-products!

**Think waste management + bio-products + sustainable energy**

***Thank you!***

**Tom Trabold**
**RIT – Golisano Institute for Sustainability**
**tatasp@rit.edu**
**585-475-4696**

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