

Converting Regional Waste Streams: Biomass and MSW Blending Strategies for Bioenergy Applications

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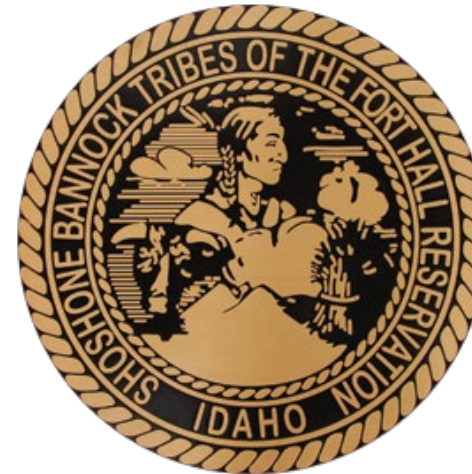
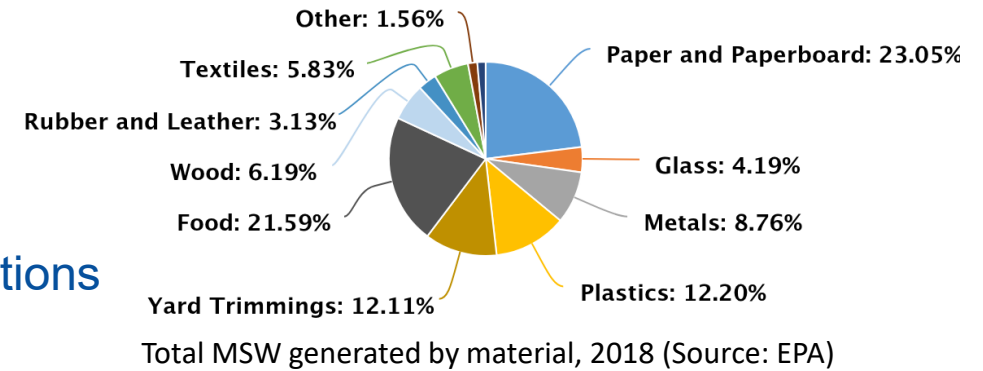
Rural waste is a wasted resource

Municipal Solid Waste (MSW)

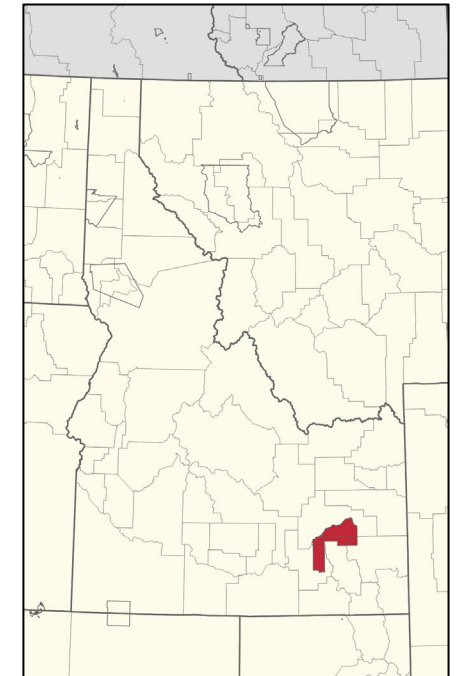
- Everyday items discarded in households, businesses, institutions
- 292 million tons of MSW generated in the US annually
 - 146 million tons landfilled
- Wastes generated in rural communities are problematic
 - Costs to handle these wastes are prohibitive
 - Likely to be burned or dumped illegally
 - Heart disease and respiratory issues
 - Soil and water contamination

Shoshone-Bannock Solid Waste Program

- Fort Hall population: 8,700 (5,900 enrolled tribal members)
- No recycling services offered
 - All waste collected on the reservation is landfilled
 - Average of 242 tons per month (~2,900 tpy)



Source: Shoshone-Bannock Tribes

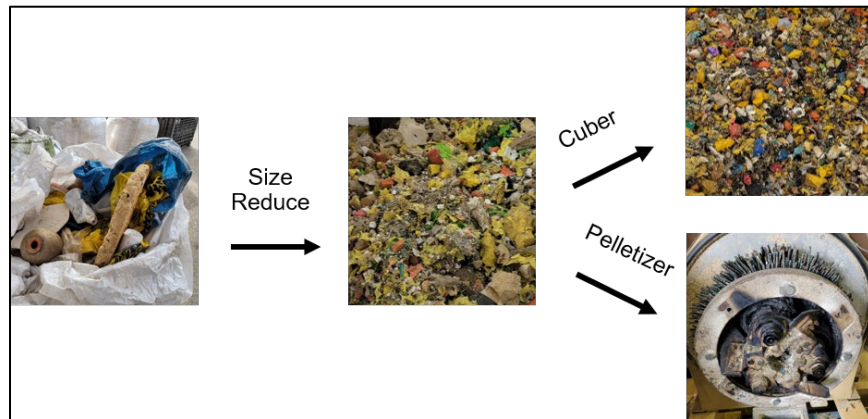


Location of Shoshone-Bannock of the Fort Hall Reservation

These materials can be used to *generate biofuels and co-products*

Value-added feedstock opportunity: Waste-biomass blending

- Together, they complement – wastes are low-cost feedstocks and can provide energy density, while energy crops offer a renewable source of carbon and enhance operational reliability
- MSW alone:
 - Additional sieving and fractional milling
 - Flowability and densification issues
 - Significantly better handling performance after mixing with biomass



MSW alone causes operational issues: melting material in pelletizer

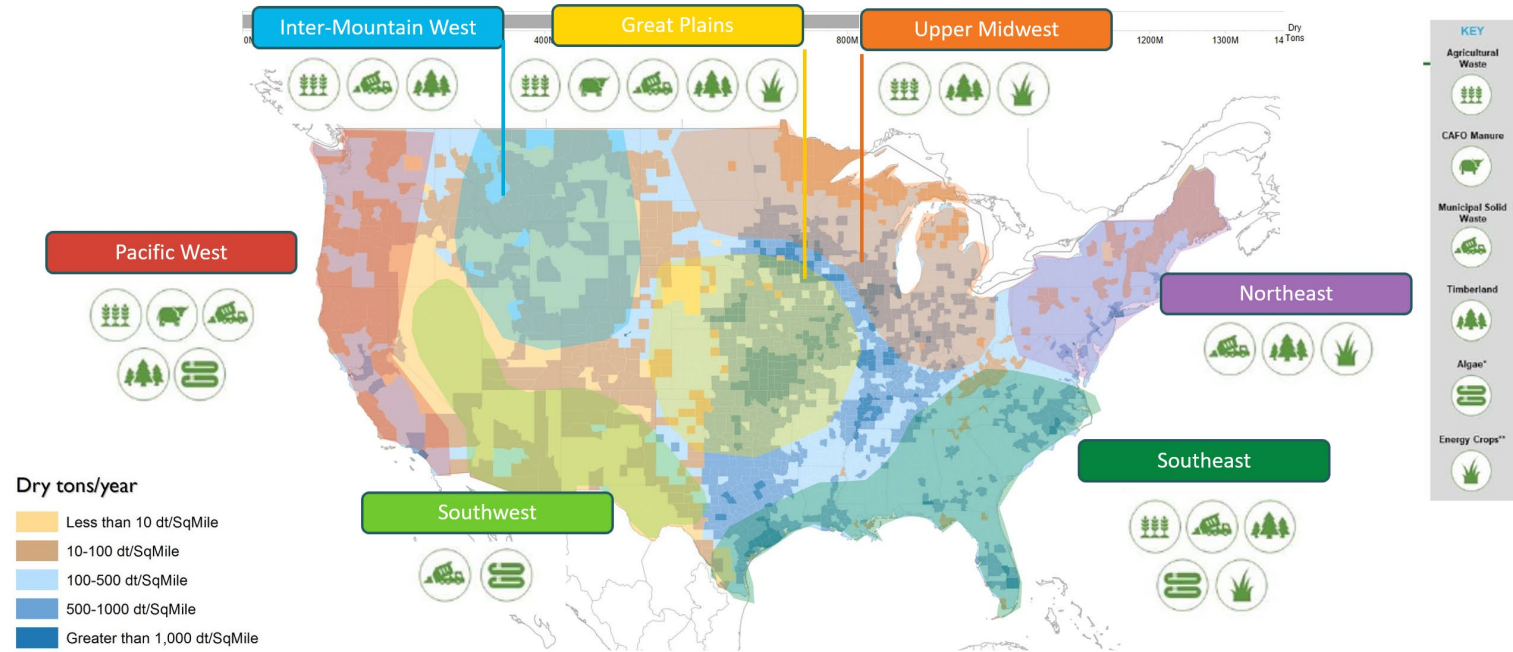


MSW + biomass: better handling, better end product

Blending waste and biomass *improves operational reliability, incorporates renewable carbon, and reduces plastic in the environment*

From resource to feedstock: Formulation approach

- Resource assessment:
 - Map co-located waste and energy-crop resources using Billion-Ton Report + Bioenergy Feedstock Library data — targeting rural overlap (Great Plains, Northeast)
 - Pair herbaceous (e.g., miscanthus) and woody (e.g., willow) energy crops with regional MSW, up to ~20% by mass
- Formulation: Validate blending strategies for conversion
 - Challenges: high variability → heterogeneous components → segregation → operational unreliability



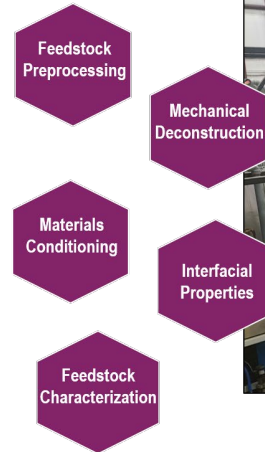
Feedstock regions, \$60/ton, product density >50 tons/square mile; Source: Billion Ton Report

Pairing regional waste with the right biomass formulation and conversion route makes it a *viable feedstock*

Engineering conversion-ready feedstock: Biomass Feedstock National User Facility (BFNUF)



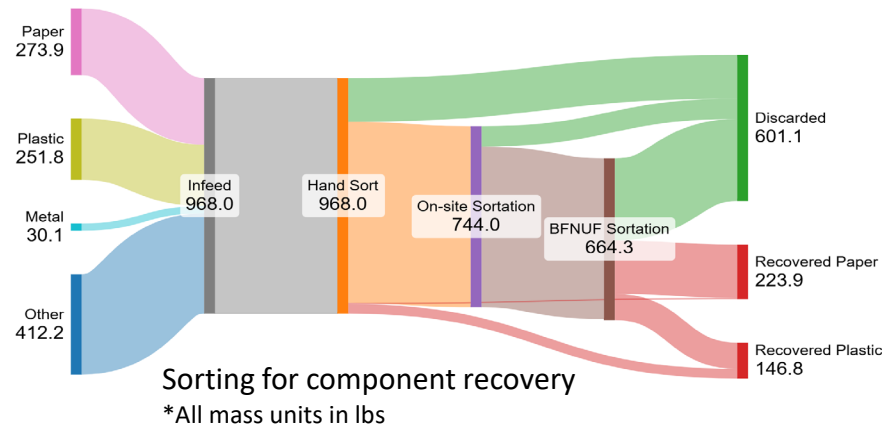
Capabilities



Solutions



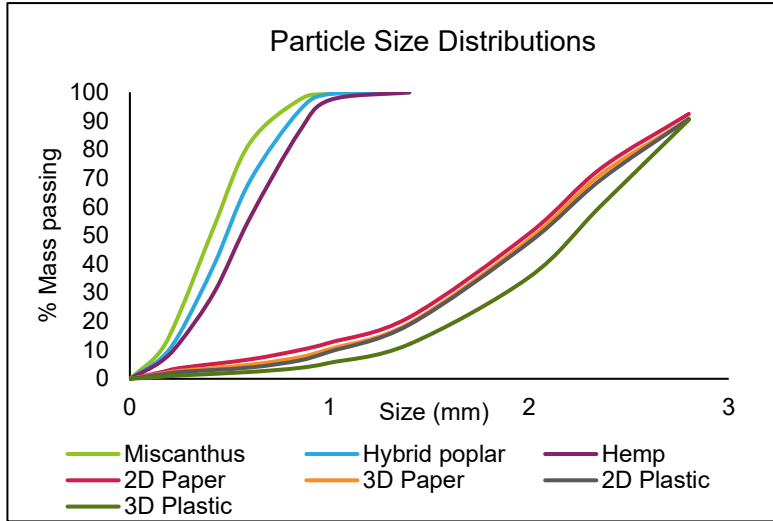
- Sorting (mechanical, pneumatic, eddy current)
- Size reduction
- Blending
- Characterization
- Densification
- Torrefaction



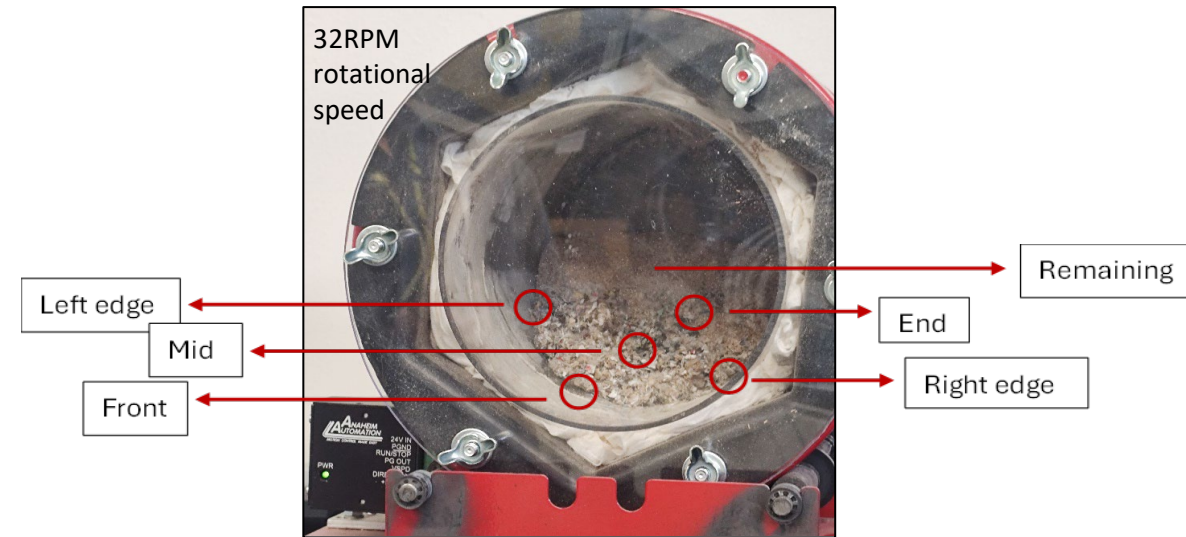
82% of Paper Recovered

58% of Plastic Recovered

Initial screening: Identifying drivers of blend quality



Material	Bulk Density (kg/m ³)
Miscanthus	233
Hybrid Poplar	227
Hemp	229
2D Paper	60
3D Paper	59
2D Plastic	64
3D Plastic	206



Benchtop rotating tumbler: Setup and sampling

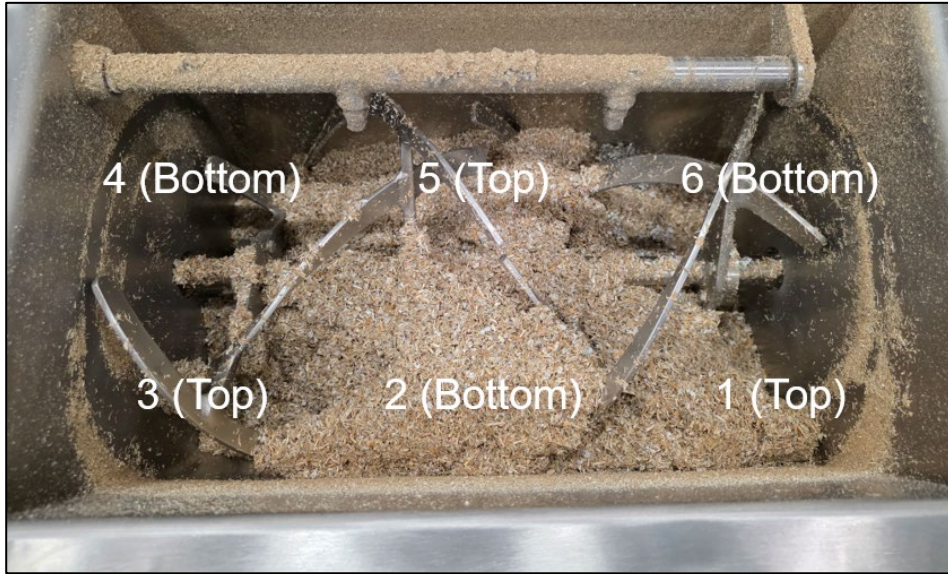
- Target blend: 20% MSW-80% biomass (mass)
- Mismatched particle size and density cause components to self-segregate
- Hemp-paper blends show highest deviation – large density difference
- Mixing time appears to have minimal effect at these test conditions

Deviation from ideal mixing and distribution of individual components

Mixture	Test time (min)	RMS difference	% MSW	% Biomass
3D Plastic-Miscanthus	1	8.19	26.16	73.84
3D Plastic-Miscanthus	1	3.75	23.40	76.60
3D Plastic-Miscanthus	3	7.17	20.92	79.08
3D Plastic-Miscanthus	5	6.84	19.46	80.54
3D Plastic-Miscanthus	10	5.69	19.21	80.79
3D Plastic-Miscanthus	10	8.20	18.93	81.07
2D Paper-Hemp	1	22.31	18.18	81.82
2D Paper-Hemp	10	13.63	17.86	82.14

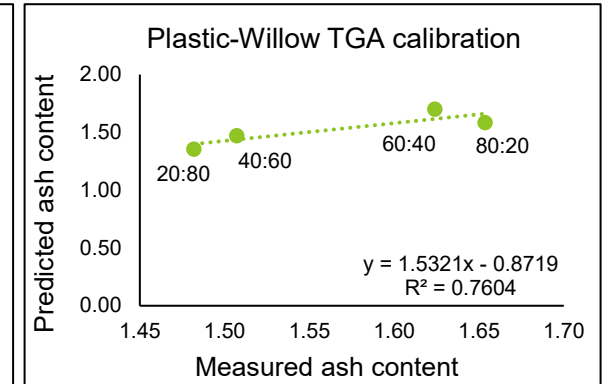
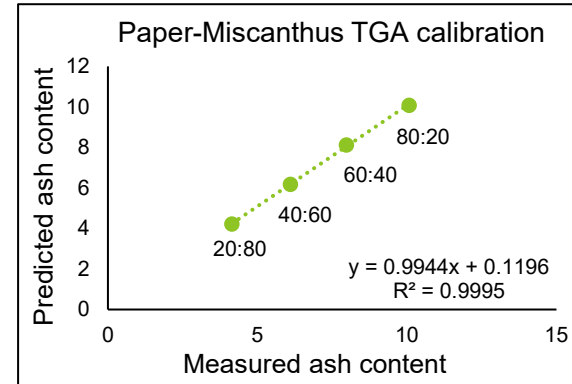
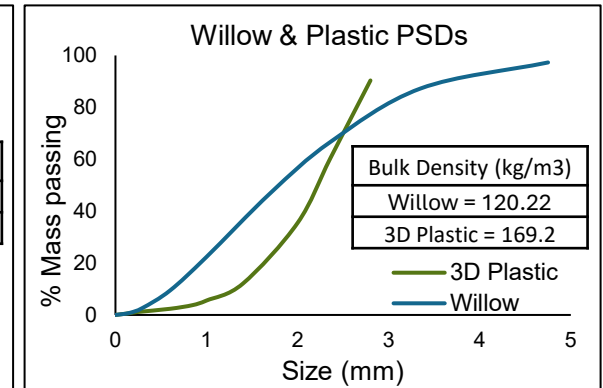
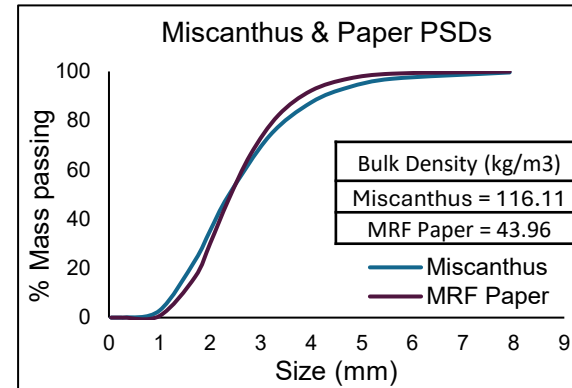
Particle size and bulk density are main drivers of segregation and blend uniformity

Evaluating mixing performance



Ribbon blender: 40RPM, 5mins; 6 sampling locations spanning spatially

- Target blend: 20% MSW-80% biomass (mass)
- Miscanthus-paper size matched; willow-plastic size mismatched
- Homogeneity tracked via component ash content using thermogravimetric analysis



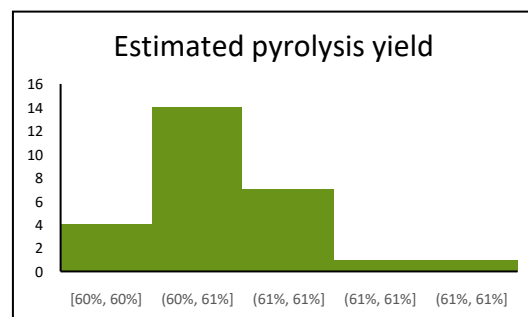
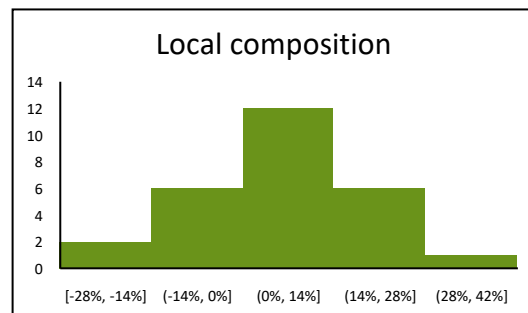
Strong ash contrast:
Miscanthus-paper (2.3% vs. 12%) — excellent linear calibration, reliable back-calculation of mass fractions

Low ash contrast:
Willow-plastic (1.82% vs 1.24%) — noisy calibration, need alternative tracking method (e.g., carbon content)

Blend uniformity – the key to consistent yields

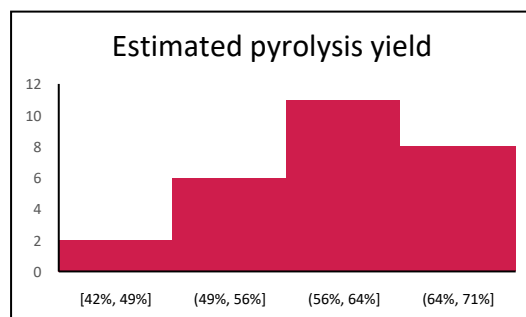
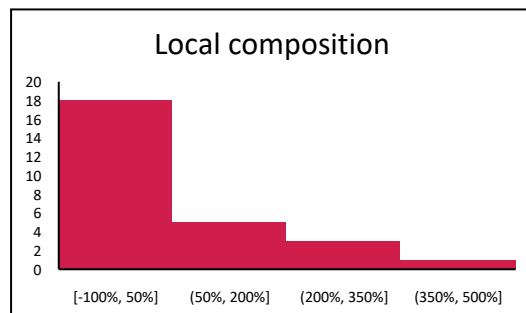
Miscanthus-Paper

Replicate	Biomass fraction (Avg)	MSW fraction (Avg)
1	0.79	0.21
2	0.81	0.19
3	0.77	0.23
Overall	0.79 ± 0.03	0.21 ± 0.03



Willow-Plastic

Replicate	Biomass fraction (Avg)	MSW fraction (Avg)
1	0.74	0.26
2	0.74	0.26
3	0.82	0.18
Overall	0.77 ± 0.24	0.23 ± 0.24



Blend test results (each replicate had 6 subsamples for TGA): Tables show component mass fractions; histograms show local composition ranges and impact on estimated pyrolysis yields

- Willow is a proven pyrolysis feedstock — whole-tree fast pyrolysis yields ~54% bio-oil (~64% clean chips) (Williams et al., 2018)
- Synergistic biomass-plastic coprocessing - co-torrefaction boosts conversion up to ~24% beyond predicted (Saha et al., 2025)
- Willow/plastic blend has the right profile— viable thermochemical feedstock

Proximate and ultimate analysis of willow, plastic and 20:80 plastic:willow blend

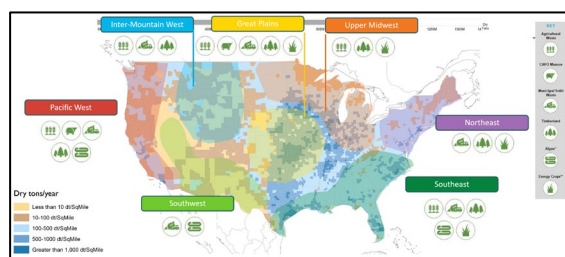
Plastic:Willow blend ratio	Moisture	Volatile	Ash	Fixed Carbon	Hydrogen	Carbon	Oxygen
0:100	4.46 ± 0.20	80.12 ± 0.56	1.82 ± 0.26	18.07 ± 0.75	7.21 ± 0.28	49.97 ± 0.33	40.61 ± 0.39
20:80	3.73 ± 0.18	82.24 ± 0.26	1.62 ± 0.18	16.14 ± 0.28	7.79 ± 0.32	53.12 ± 0.08	37.11 ± 0.22
100:0	0.50 ± 0.13	94.07 ± 0.26	1.24 ± 0.23	4.68 ± 0.29	11.59 ± 0.09	72.33 ± 1.03	14.74 ± 0.96

- Estimated individual yields: Miscanthus (62%), Paper (55%), Willow (65%), Plastic (40%)
- Miscanthus-paper blends uniform and repeatable - data tightly clustered ($\sigma = 0.03$)
- Willow-plastic blends highly variable - ($\sigma = 0.24$, 8× scatter)

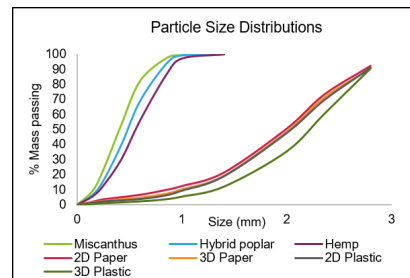
Local mixing uniformity is critical when component thermochemistry and yields are different

The takeaway: Turning blending into a design tool

- Rural waste is an untapped resource and formulating waste-biomass blends can enhance feedstock quality
- Particle size and density are prominent drivers of blend uniformity – preprocessing needs to be optimized to match process needs
- Local mixing uniformity is critical when component thermochemistry and yields are different
- Next steps include developing digital models (e.g., DEM simulation) for predictive control and further assessing the impact of material properties (size, density, shape) and operating conditions (blender speed, residence time, fill level)

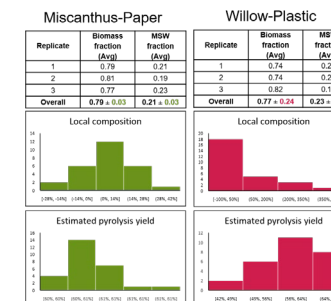
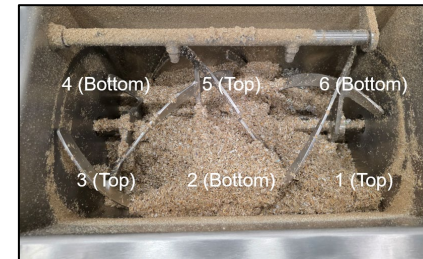


Resource assessment



Preprocessing

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3D Plastic	206



Blend uniformity

Digital models for predictive control

From demonstrated blends to predictive control — making waste a more *reliable feedstock*

Thank you

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