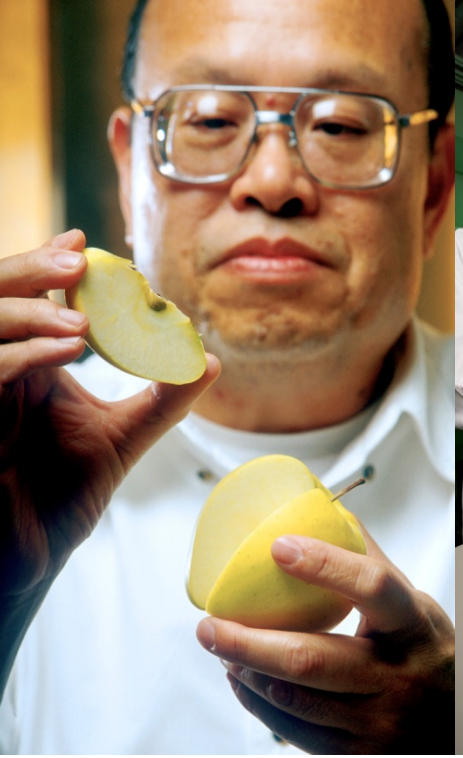



Optimizing biorefinery infrastructure toward "zero waste" agricultural

William Orts – Research Leader, Bioproducts
USDA Western Regional Research Center

15 April 2021

USDA

USDA Western Regional Research Center

USDA ARS
Agricultural Research Service

Known for biotechnology especially crop biotech.

~390 people

~50 in Biofuels/ & Bioproducts

Energy Policy: The way things are supposed to be…..

Renewable Fuel Standard-2 (RFS2). It's the law!

36 billion gallons/year by 2022

Biofuels Technology	2020 Statutory*	2020 Final	
Corn grain ethanol	15*	13.8	←
Biomass – Biodiesel	1.5	2.4	←
Advanced biofuels	12	5.1	} Need to catch up!
Cellulosic biofuels	10.5	0.6	
Total biofuels	30++	21.9	

* Targets are adjusted yearly.

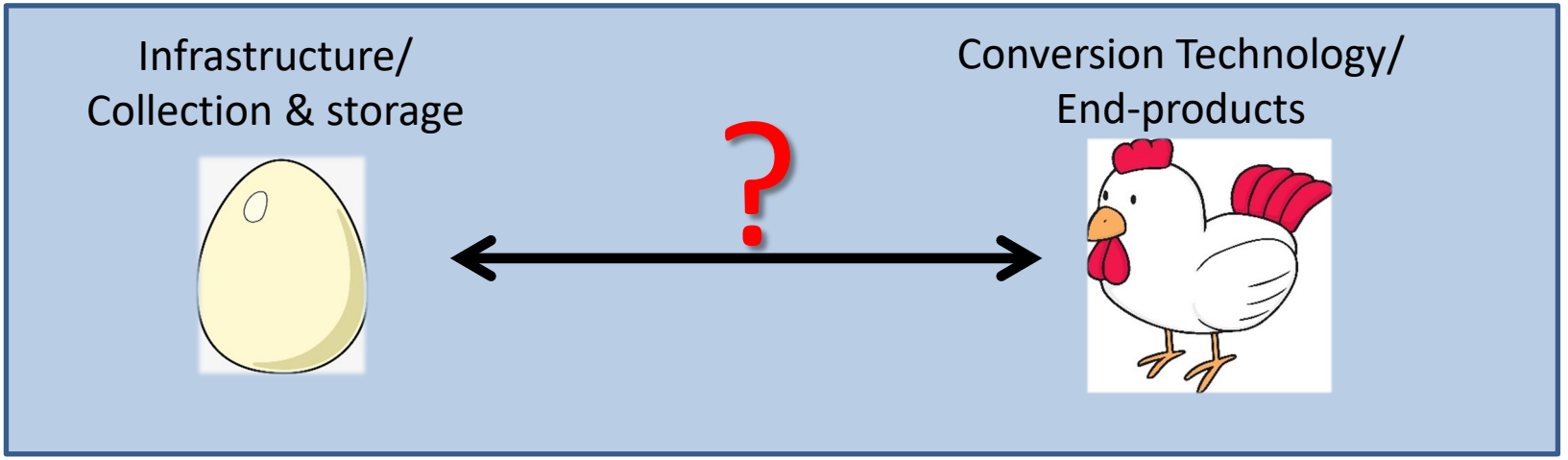
Straw for cellulose-to-ethanol

ISSUES:

- Straw varies with seasons
- Aging ⇔ harvest time is once per year
- Moisture and storage are challenging
- Transportation ⇔ Low density
- Supply is not near highest demand.

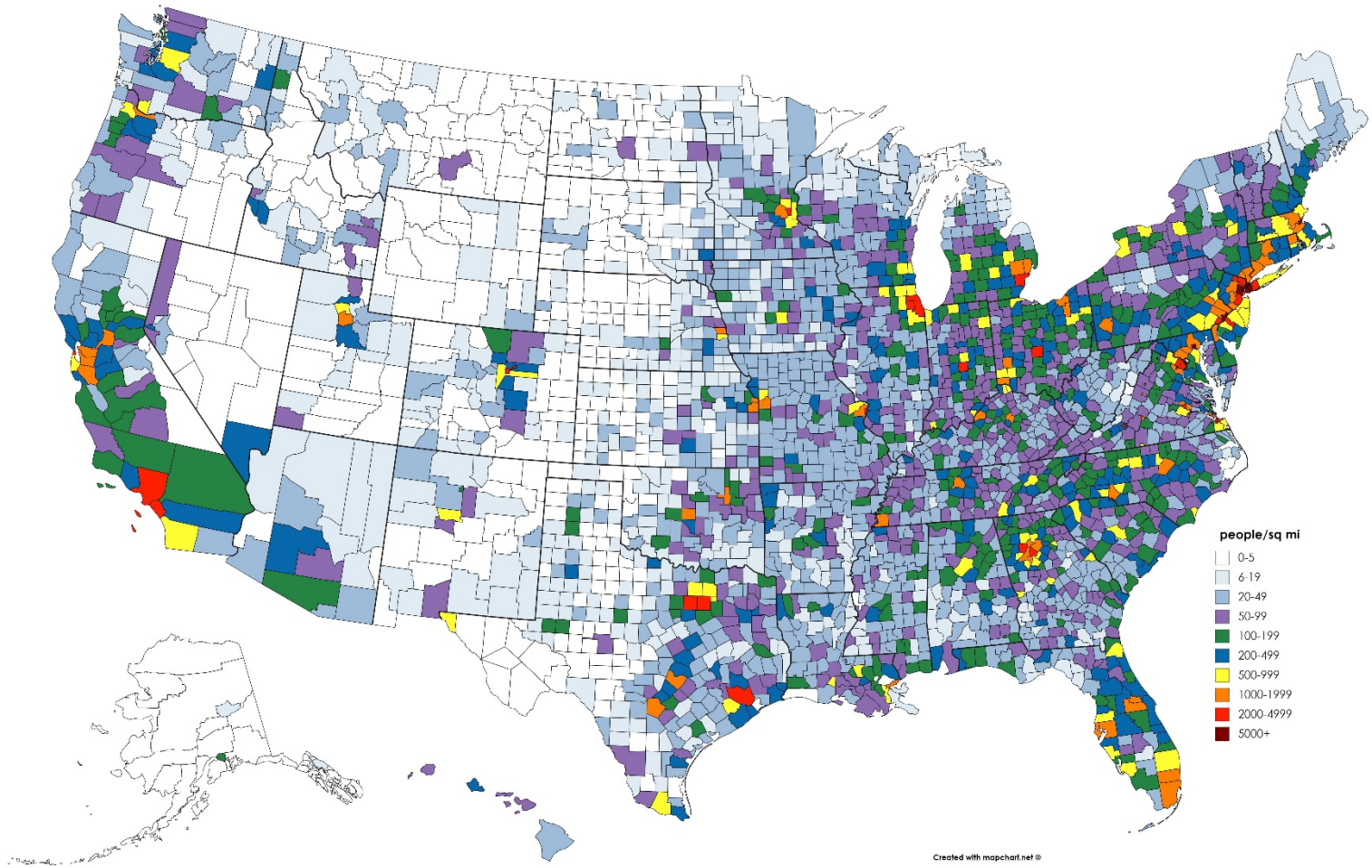
Introduction

- **Which comes first, the infrastructure or the bioproduct market?**
  - Optimizing Ag-derived bioproducts



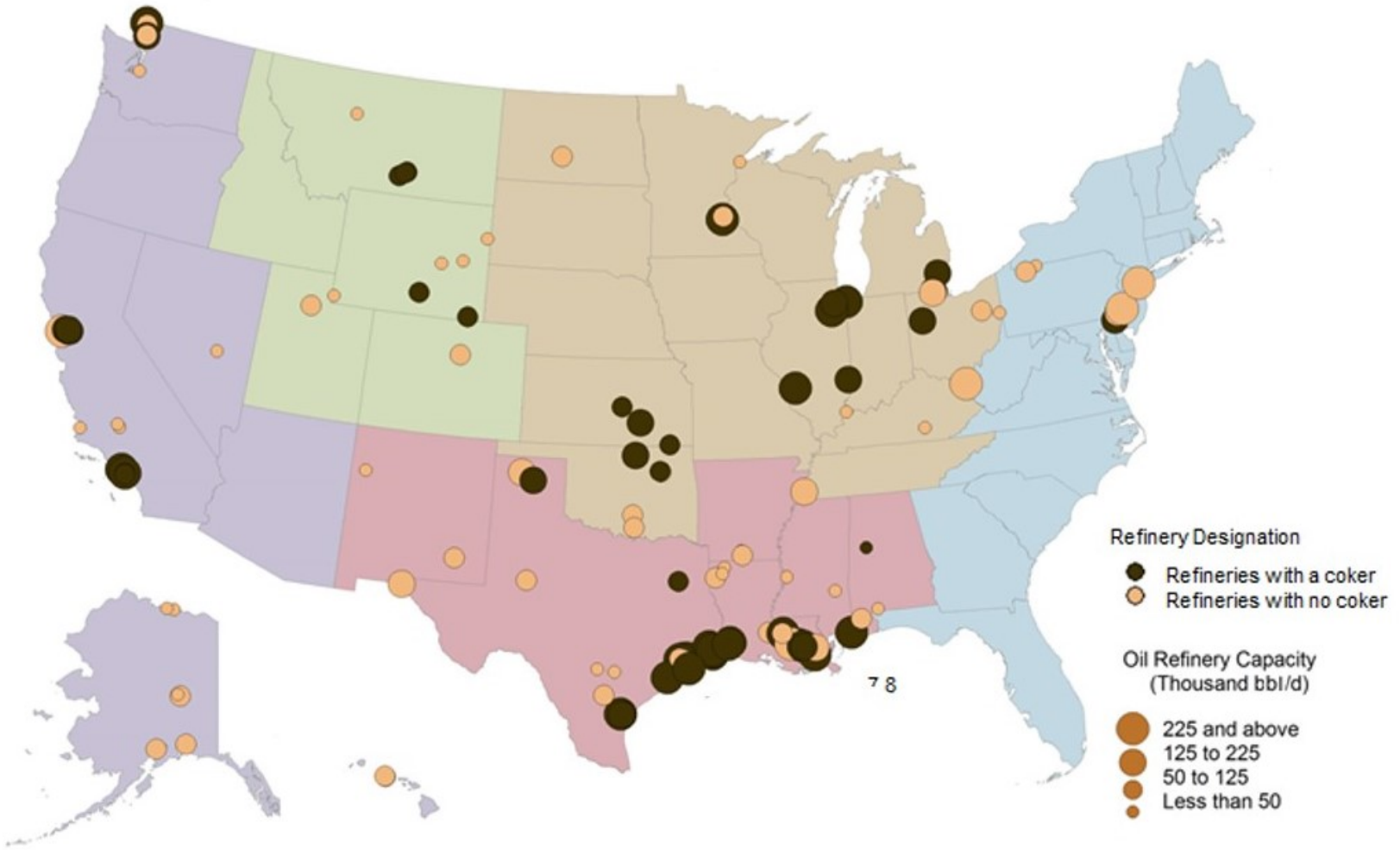
- **"Zero waste" agricultural will be regionally specific.**
  - New uses for almond coproducts
- **Infrastructure progress will be step-wise ⇔ no single answer.**
  - Biorefineries are ⇔
    - Grain mills & ethanol plants,
    - Landfills, wastewater treatment facilities, MRFs
    - Large food processing plants, etc.
- **Multi-institutional collaboration across industries, agencies and regulators will be essential.**

U.S. Population Density



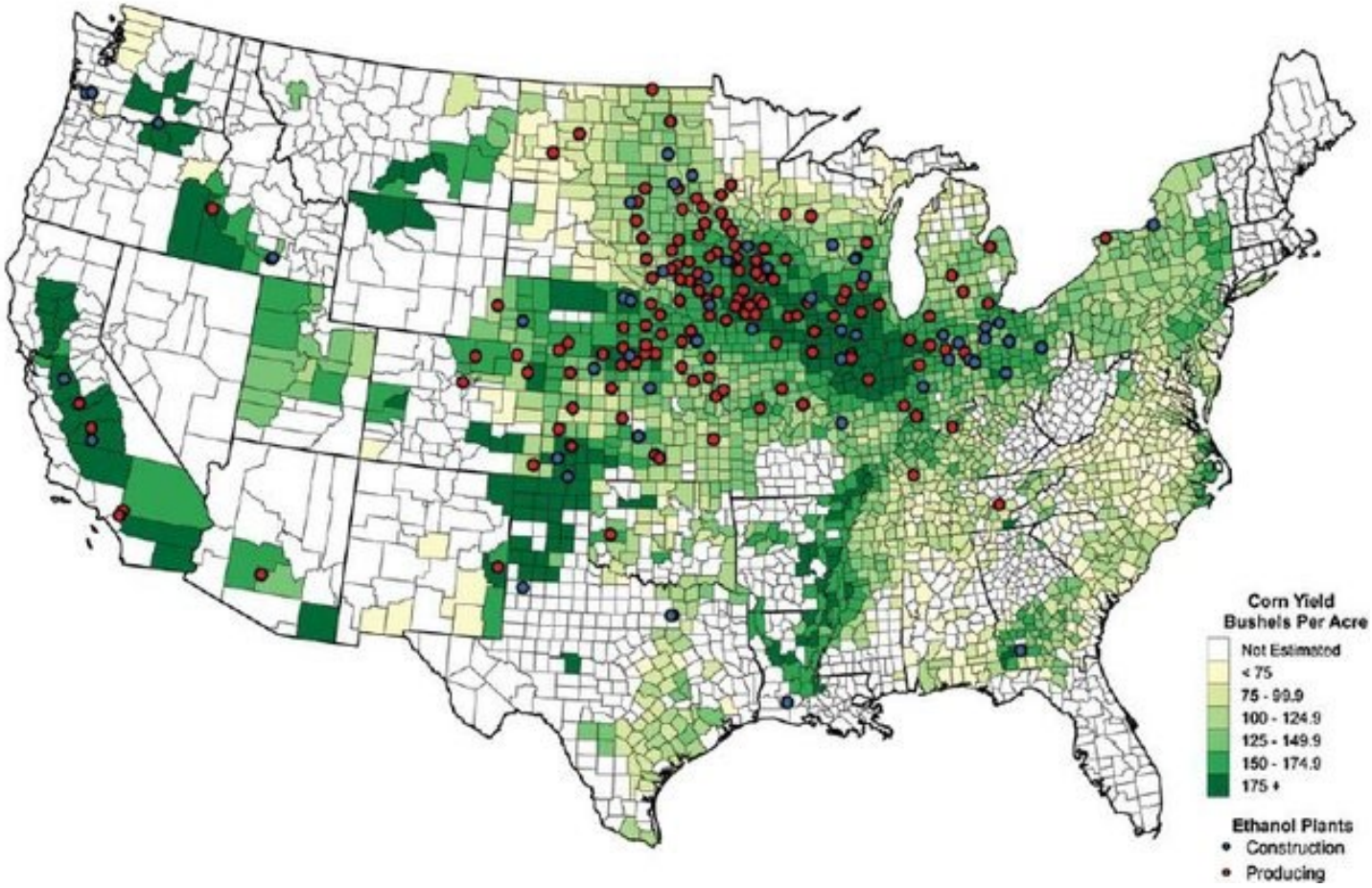
https://www.reddit.com/r/MapPorn/comments/8njjhx/the_population_density_of_the_us_by_county/

U.S. Oil Refineries



https://www.eia.gov/todayinenergy/detail.php?id=19591

U.S. Ethanol Plants: Biorefineries



https://ethanolrfa.org/biorefinery-locations/

Integrated Biorefinery Based on MSW and Ag-Derived Biomass

USDA

jbei
Joint BioEnergy Institute

Salinas Valley
Solid Waste Authority
Promoting the Environmental Health of the Salinas Valley

CR³ Autoclaves:

- Pressurized hot water treatment.
- Reduces volume.
- Isolates recyclables
- Fractionates components

Salinas Crazy Horse Landfill

SALINAS VALLEY
SOLID WASTE AUTHORITY
Promoting the Environmental Health of the Salinas Valley

Conveyor loading MSW to autoclave

MSW in the autoclave prior to treatment

MSW after steam treatment

Post-Autoclave MSW Sorting

3/8” ½” 1”

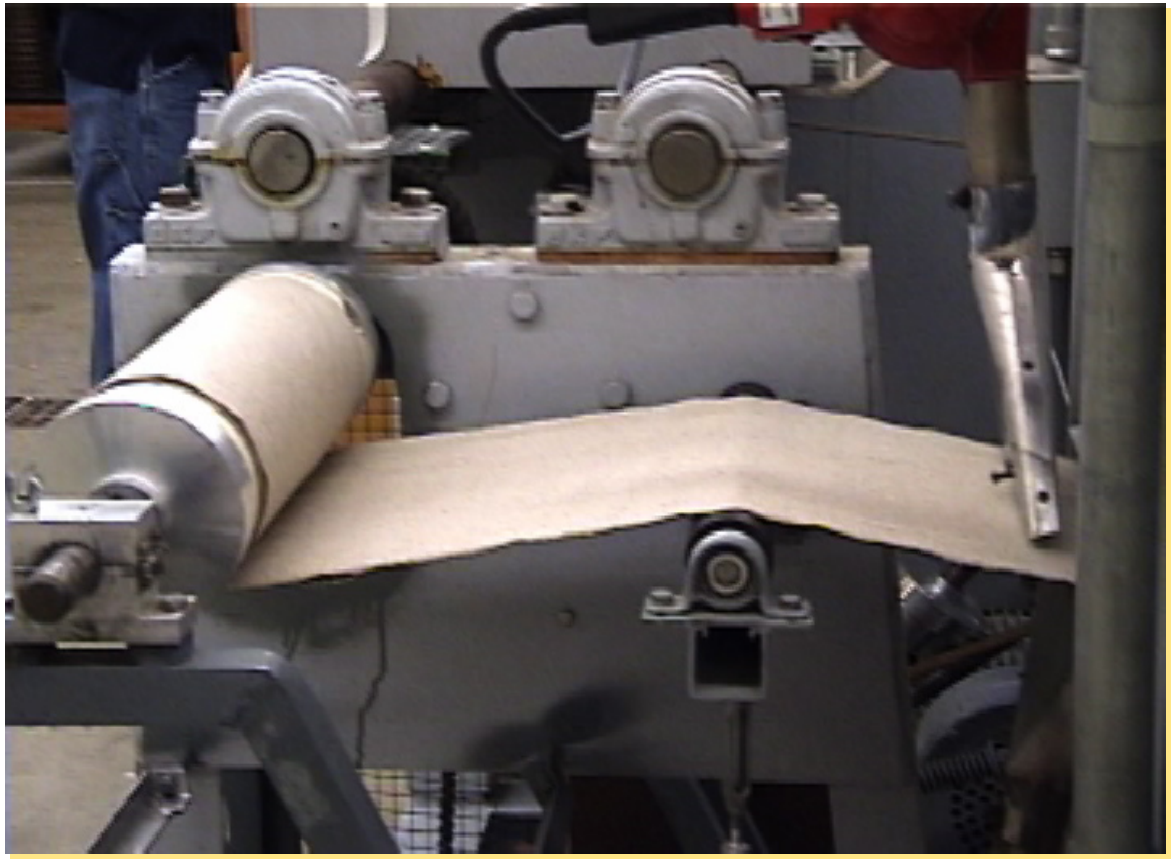
Trommel Screen Side View

Trommel Screen Frontal View

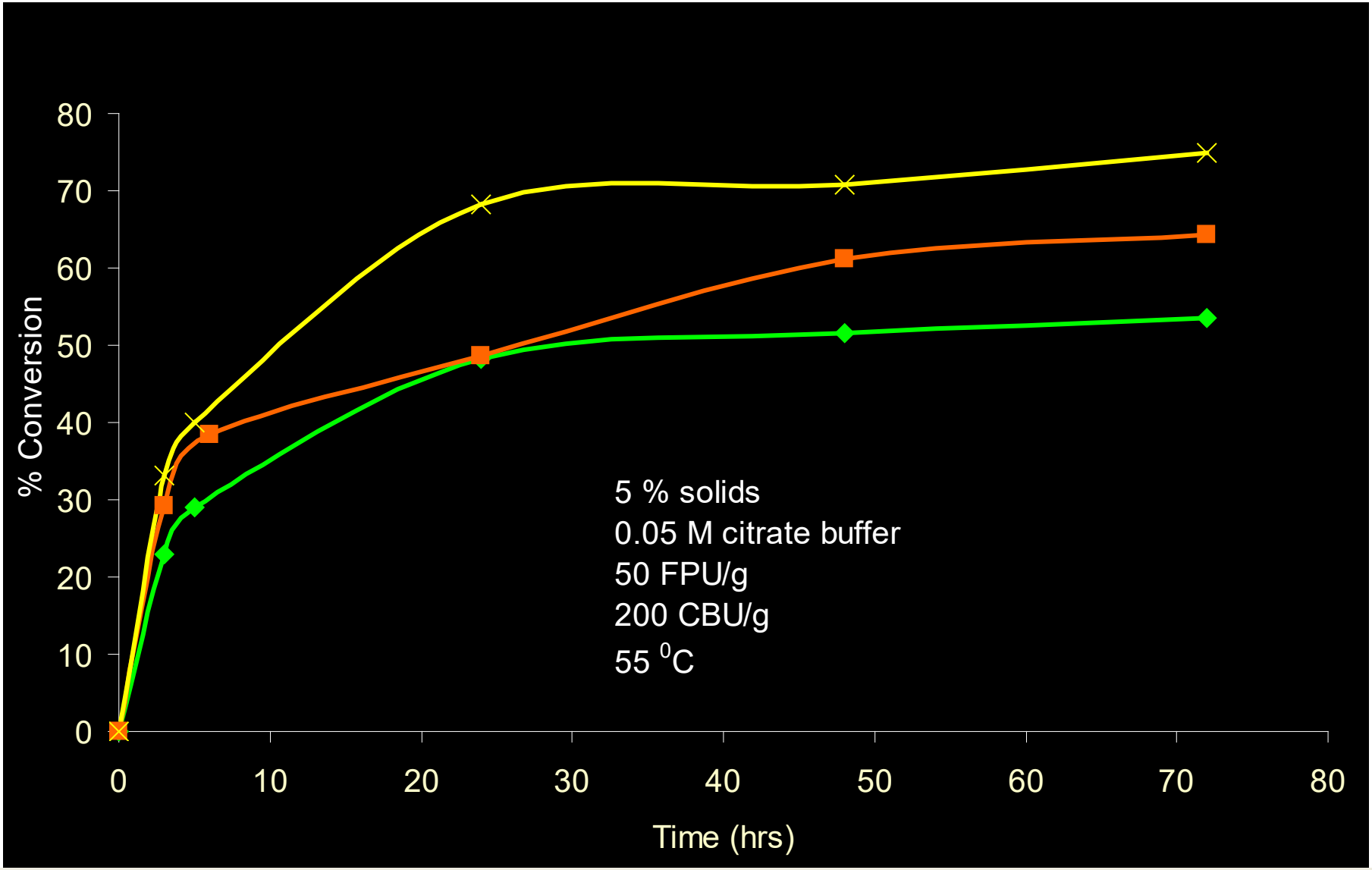
Clean fiber from MSW after centrifugal cleaners

Cellulose from Autoclaved MSW

Processed paper from recovered fiber



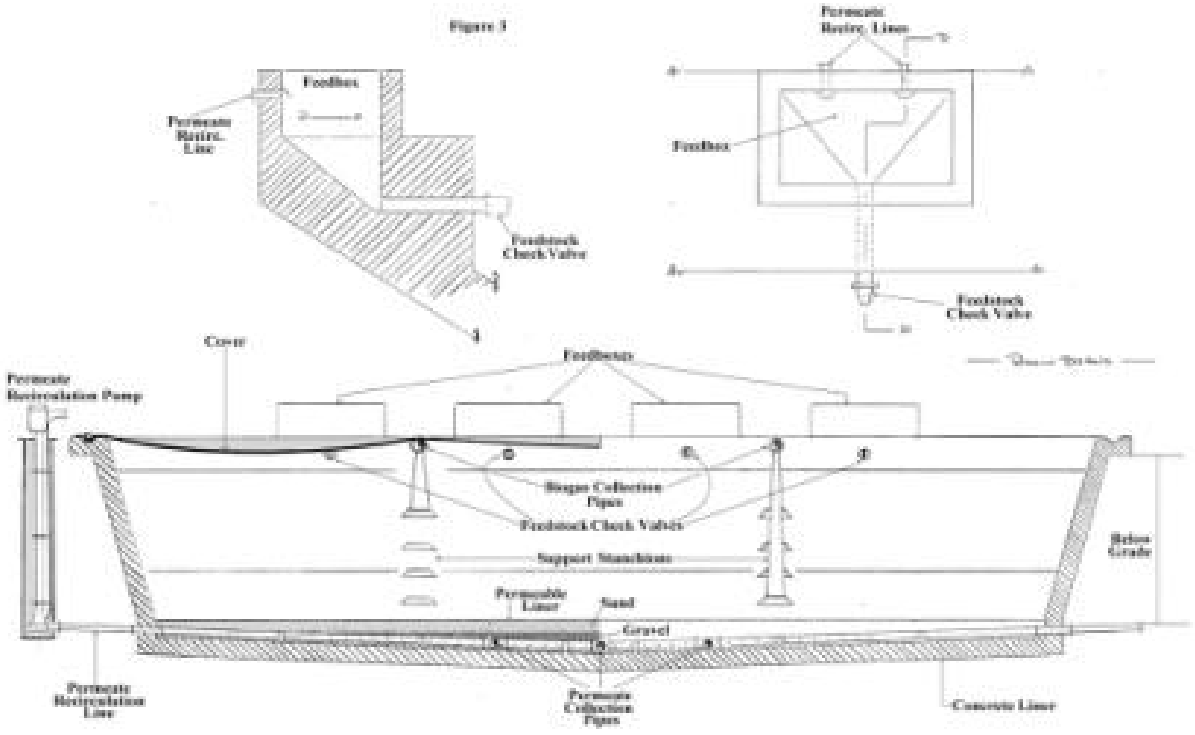
Enzymatic hydrolysis of MSW



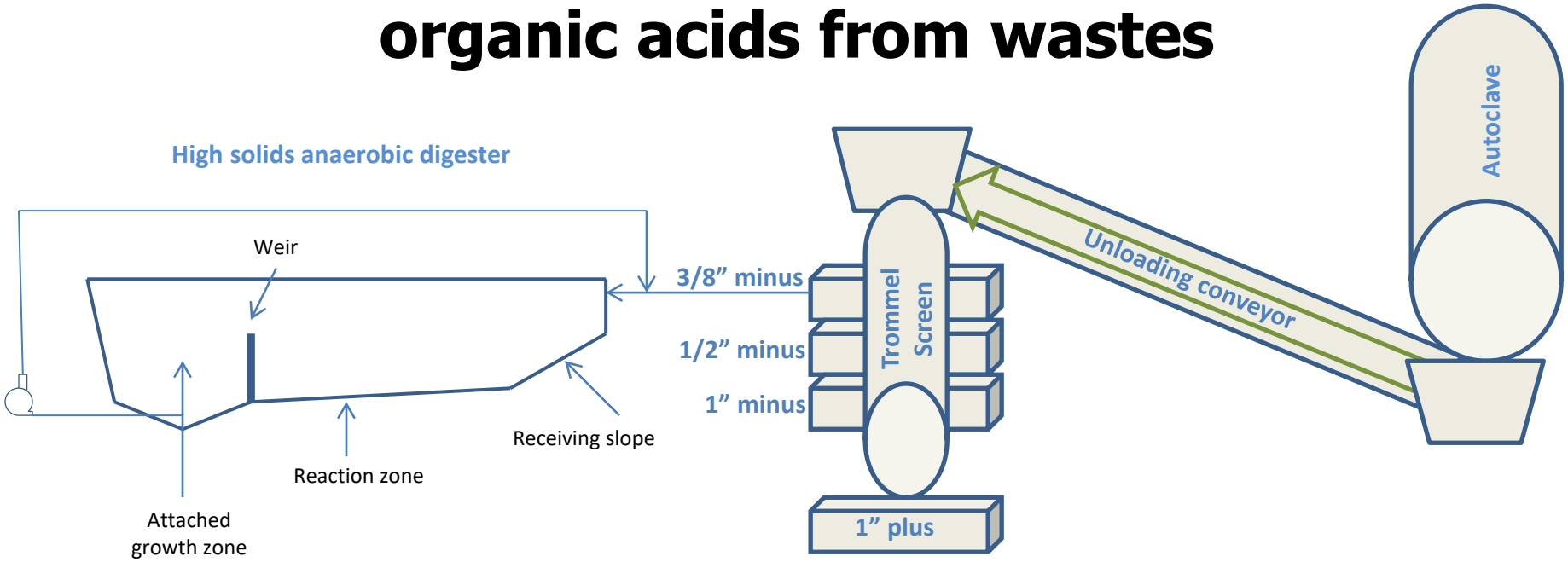
Anaerobic digestion ⇔ Biogas

Due to flexibility in cost and scale, anaerobic digestion (AD) is highly recommended in today's economic climate.

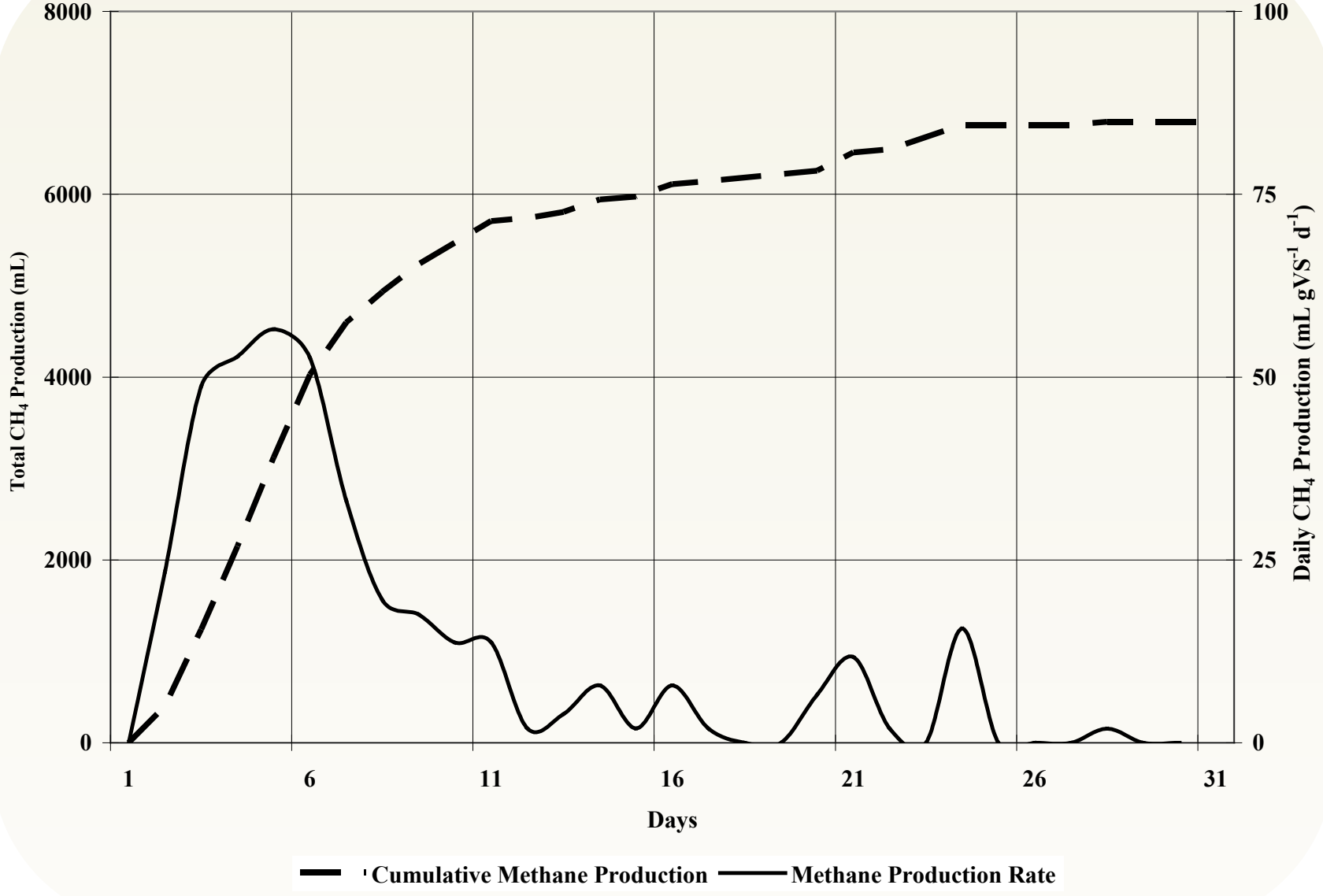
- it scales well from larger to smaller.
- smaller capital cost (can produce fertilizer for ag-use)
- fits into current engine technologies and infrastructure.
- can be used to replace electricity (coal), diesel/gasoline, LPG.
- transports well.
- reduces emissions.



Anaerobic digestion: Methane and organic acids from wastes



Gas production for a slug feed of MSW pulp (20 g) in a 5 L CSTR with an SRT of 30 days.



One life-cycle analysis published in Science (May 8, 2008), concluded that bioelectricity produces an average 81% more transportation kilometers and 108% more emissions offsets per unit area cropland than cellulosic ethanol through either production of electric cars or through use of liquefied biomethane.

Compressed Biomethane vs Ethanol

Ethanol

- **Achieve 70 gallons per mt of autoclave pulp product (dry basis).**

Biomethane

- **Achieve 428 mL CH_4/g VS with MSW pulp.**
- **99 diesel equivalent gallons per mt of autoclave pulp product (dry basis).**
- **155 ethanol equivalent gallons per mt of autoclave pulp product (dry basis).**

Thermal Properties of Poly(ethylene terephthalate) Recovered from Municipal Solid Waste by Steam Autoclaving

Kevin M. Holtman,[1] Alice Kodama,[1] Artur P. Klamczynski,[1] Allison Flynn,[2] David V. Bozzi,[1] Lennard Torres,[2] Diana Franqui-Villanueva,[1] Jingdong Mao,[3] Gregory M. Glenn,[1] William J. Orts[1]

[1]*U.S. Department of Agriculture—Pacific West Area, Agricultural Research Service, Western Regional Research Center, Bioproducts Chemistry and Engineering, 800 Buchanan Street, Albany, California 94710*
[2]*E. Khashoggi Industries Limited Liability Corporation, 800 Miramonte Drive, Santa Barbara, California 93109*
[3]*Department of Chemistry and Biochemistry, Old Dominion University, 4541 Hampton Boulevard, Norfolk, Virginia 23529*

Journal of Applied Polymer Science 2012, *126* (5).

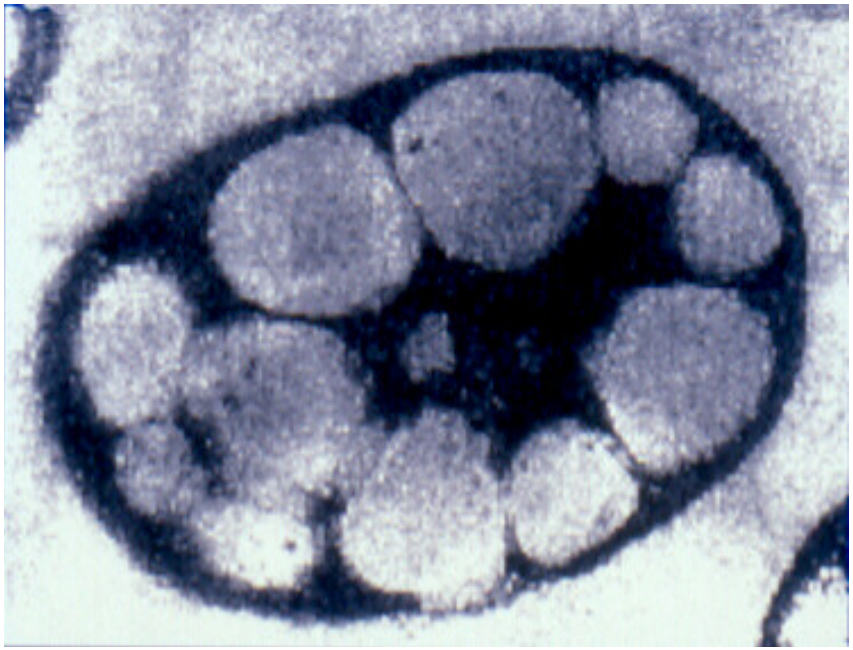
Carbon Intensity

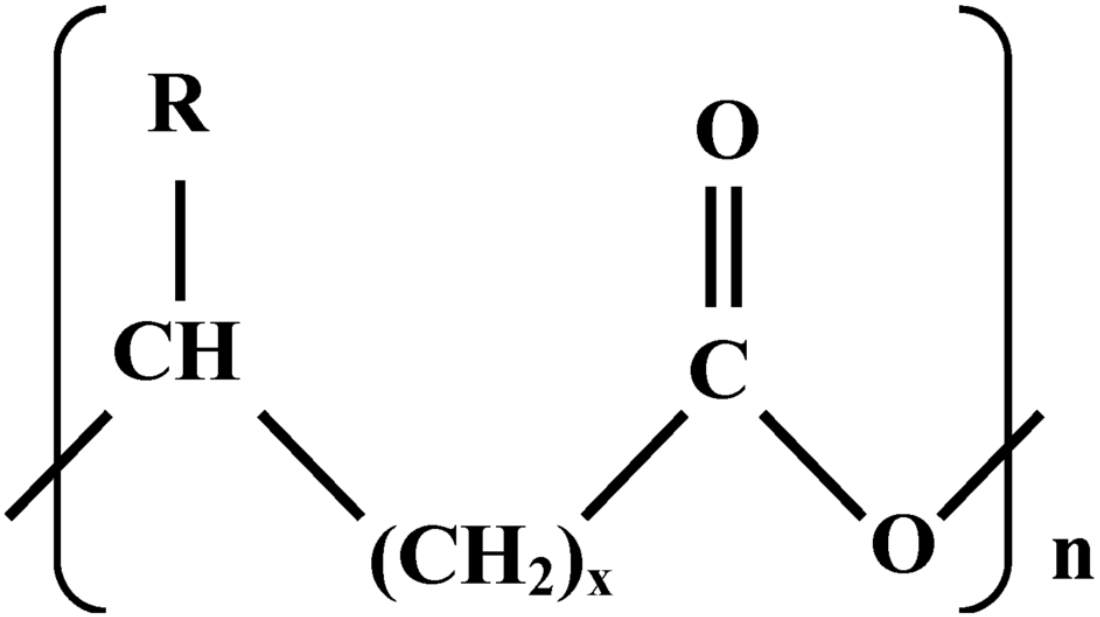
Fuel	Pathway	Carbon Intensity Values (gCO_2/MJ)		
		Direct Emissions	Indirect/ Land Use Emissions	Total
Gasoline	CARBOB –Avg. California refinery	95.9	---	95.9
Corn Ethanol	Midwest Dry Mill; Wet DGS; 80% NG; 20% Biomass	56.8	30	86.8
Corn Ethanol	California Dry Mill; Dry DGS; 80% NG; 20% Biomass	54.2	30	84.2
CNG	California NG via pipeline;	67.7	---	67.7
CNG	Landfill gas (bio-gas) cleaned to pipeline quality.	11.3	---	11.3
CNG	Dairy Digester Gas, cleaned to pipeline quality.	13.5	---	13.5

(http://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf)

PHA Biorefineries:
PolyHydroxyAlkanoates

properties similar to polypropylene



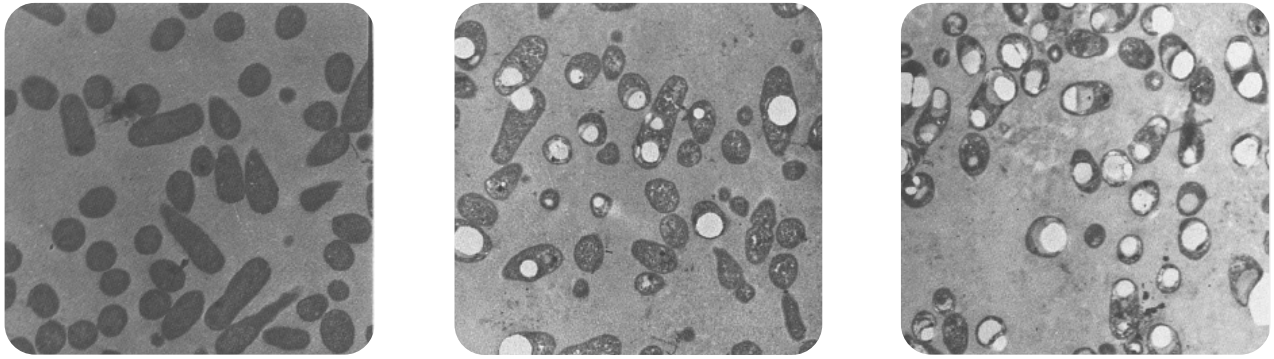


Methanotrophs producing P(HB-co-HV)

- PHA is produced when excess carbon is present and/or when a key nutrient is limiting

Balanced growth conditions

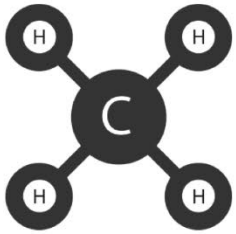
Carbon excess and/or nutrient deficiency; PHA granules begin to form



Daniel et al (1992)

- Type II methanotrophic bacteria produce PHA.
- Strain, *Methylocystis* sp. WRRC1 was capable of producing a wide range of polyhydroxybutyrate-co-hydroxyvalerate copolymers (PHB-co-HV) when co-fed methane and valerate or n-pentanol.

Waste facility

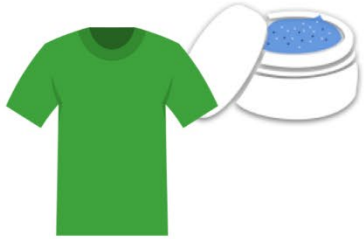


Methane gas emissions

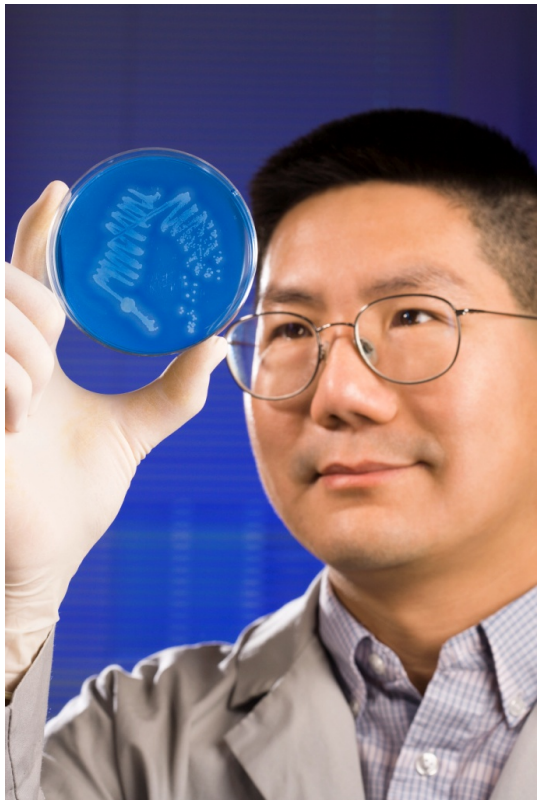
Microbial process

MANGOMATERIALS™

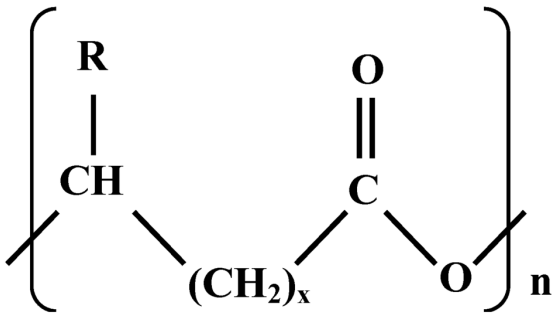
PHA biopolymer



Biodegradable products



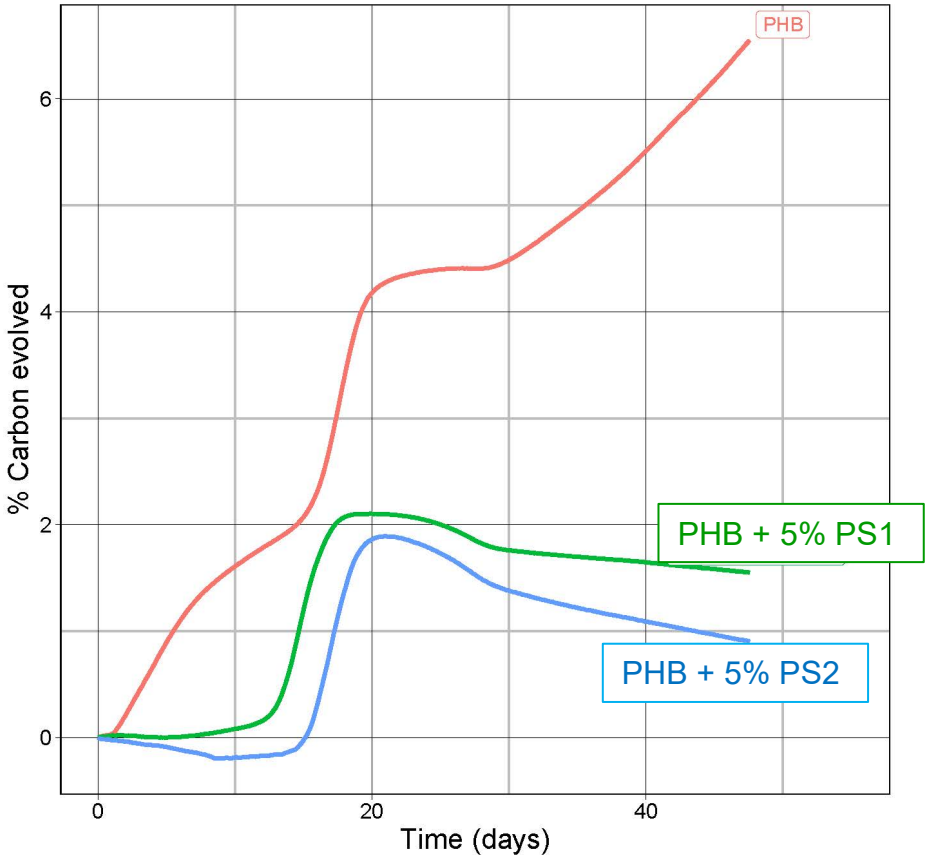
MANGO MATERIALS



PHA fibers from Ag-Wastes

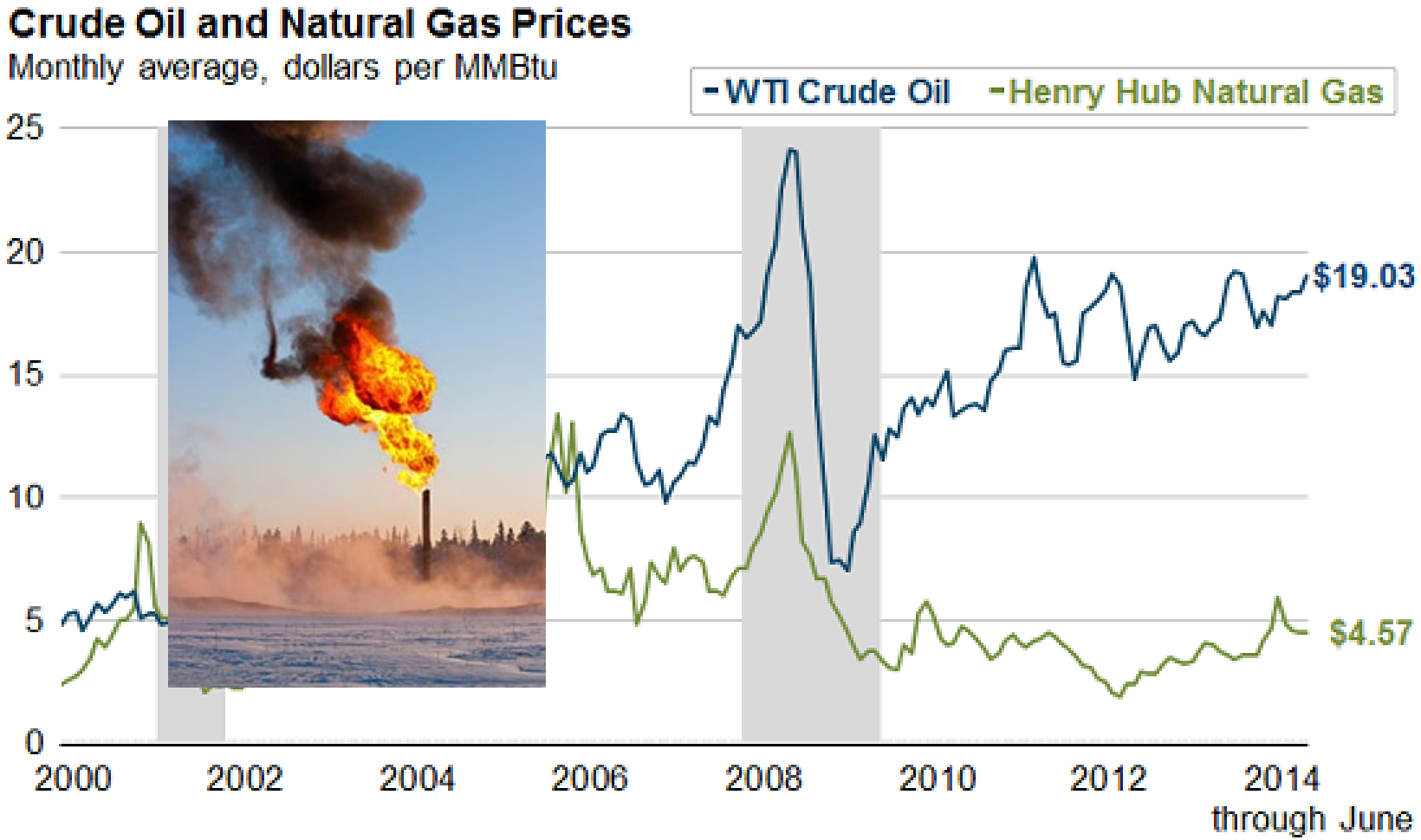
PHB modification to decrease rate of biodegradation

Low levels of polysaccharide additives dramatically reduces biodegradation rate



MANGO MATERIALS

Natural Gas vs Oil Prices

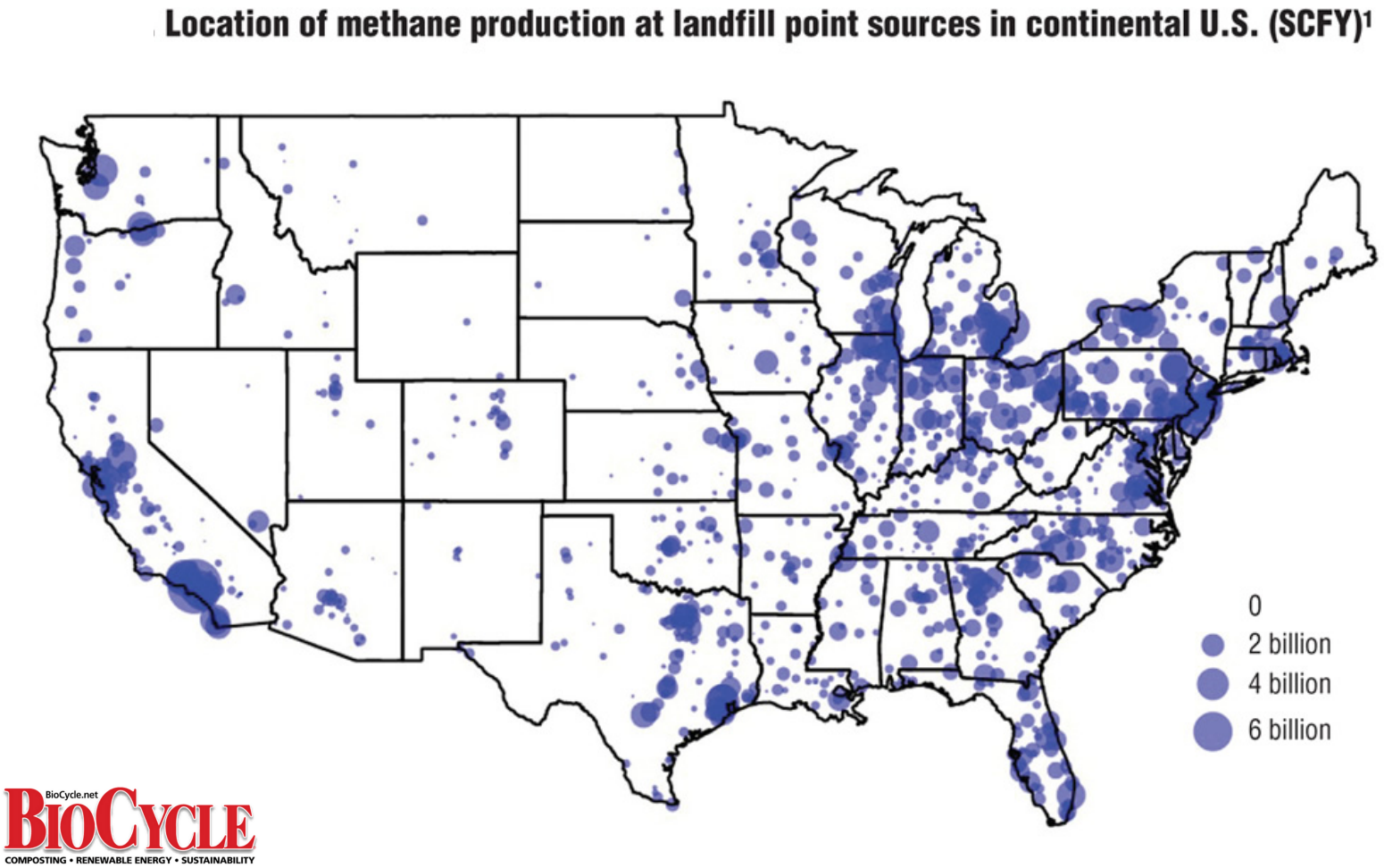


Note: Oil prices have been converted to dollars per million BTU for ease of comparison.

Sources: *Wall Street Journal*, U.S. Energy Information Administration, Atlanta Fed calculations

http://farmdocdaily.illinois.edu/2011/11/trends_in_crude_oil_and_natura.html

Landfills and their Methane Potential

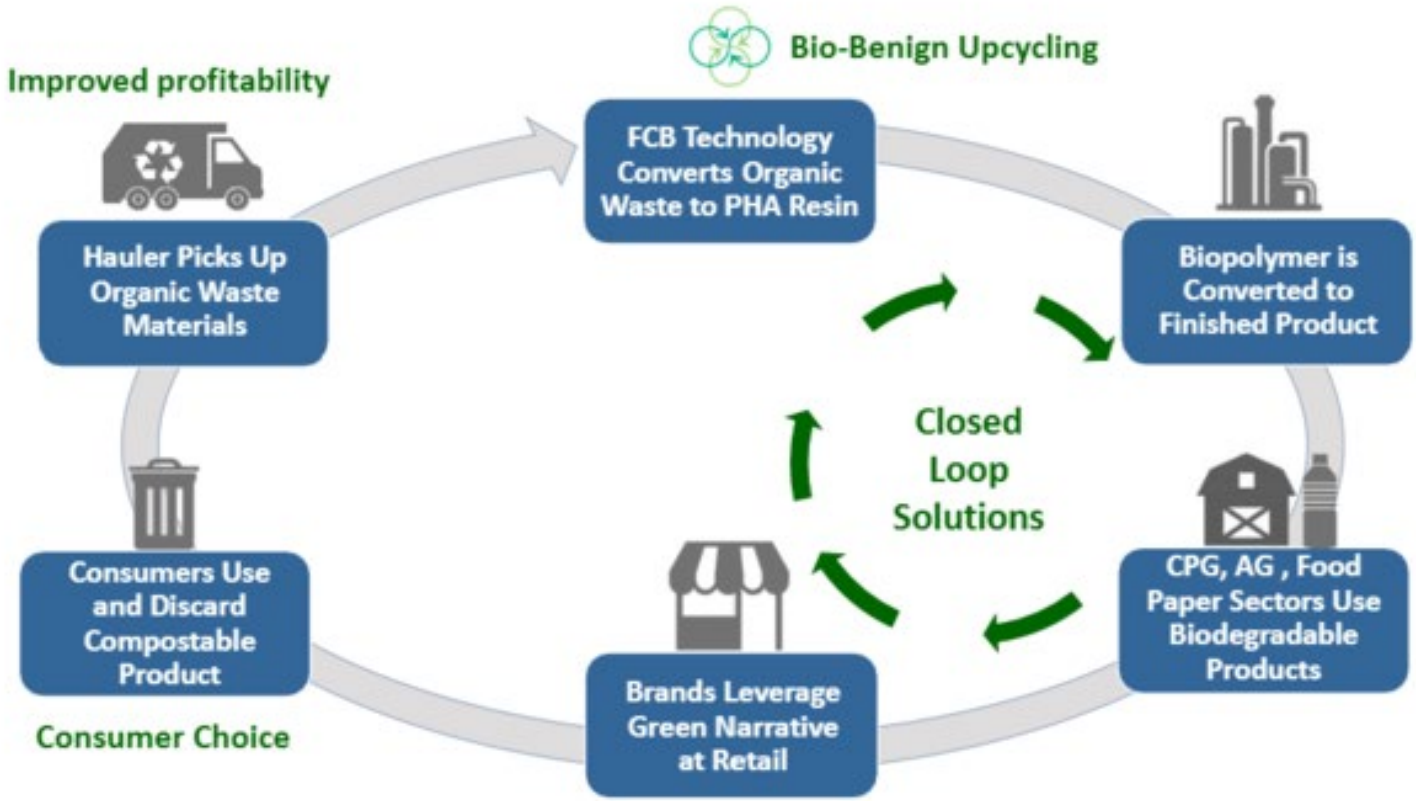


A.E. Schauer-Gimenez, A.J. Cal, M-C. Morse, A.J. Pieja, K.M. Holtman and W.J. Orts BioCycle November 2014, Vol. 55, No. 10, p. 43

FULL CYCLE

Bioplastics for the Circular Economy

A Meaningful Circular Economy Solution



Conclusions/ Comments

- Building biorefineries does not require us to build from scratch
  - Biorefineries are ⇔
    - Landfills
    - Wastewater treatment facilities
    - MRFs
    - Large food processing plant
    - Etc.,
- There is no single answer – Solutions will be regional.
- Build the infrastructure along with the technology.
- Multi-institutional collaboration across industries, agencies and regulators will be essential.

Acknowledgements

Salinas Valley Solid Waste Authority
Promoting the Environmental Health of the Salinas Valley

MANGO MATERIALS

CORUMAT
BETTER MATERIALS

FULL CYCLE
Bioplastics for the Circular Economy

Almond Alliance of California

california almonds

California Walnuts
www.walnuts.org

Recology
WASTE ZERO

F-D-S Manufacturing Co.
Since 1950

TITUS
MRF SERVICES

RPAC LLC
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TRANPAK

Funded By
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