

Wastewater Treatment Facilities: A Source of Oil for Producing Biodiesel

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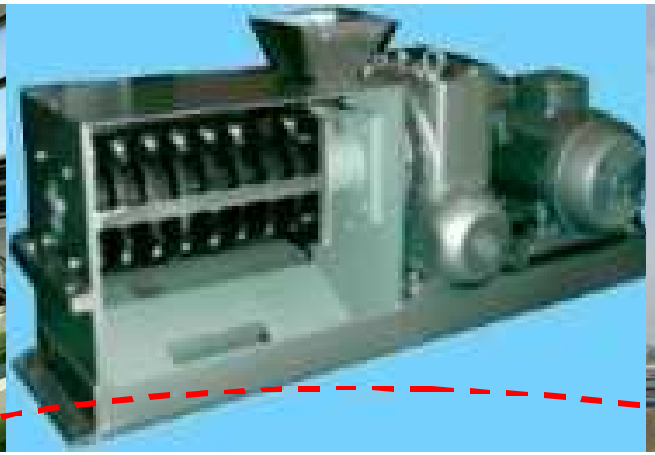
Biodiesel Industry: Present & Future Challenges

- Total US BD usage is ~80 Mgal/yr
- US uses ~75 Bgal/yr of Petro-Diesel
- Total oleochemical production capacity is ~500 Mgal/yr
- More than 70% of current biodiesel production cost is the feedstock
- There is a glut of crude glycerine in the market
- Current price of crude glycerine is ~ $0.01/lb compared to $0.60/lb in 2000.
- Many biodiesel producers are storing crude glycerine

DOE SERC Biofuels Research & Development at MSU

Lipid Source Production

- Plant Sciences
- Biochemistry
- Chemical Engineering

Lipid Extraction

- Chemical Engineering
- Chemistry
- Plant Sciences
- Biochemistry

Biofuel Production

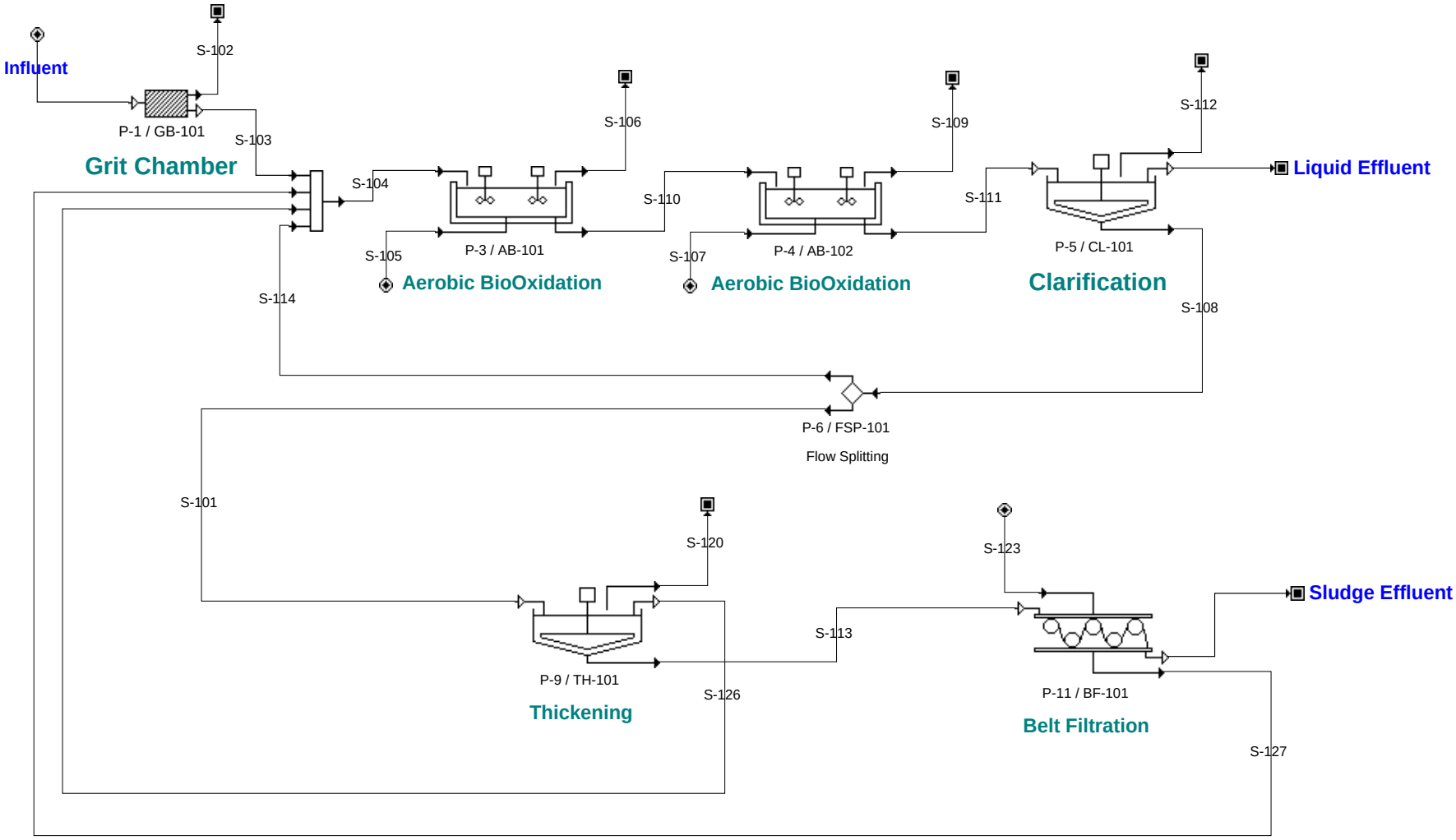
- Agricultural and
- Biological Engineering
- Chemical Engineering

Biofuel Market Development

- Food Sciences
- Chemical Engineering
- Agricultural Economics
- Mechanical Engineering

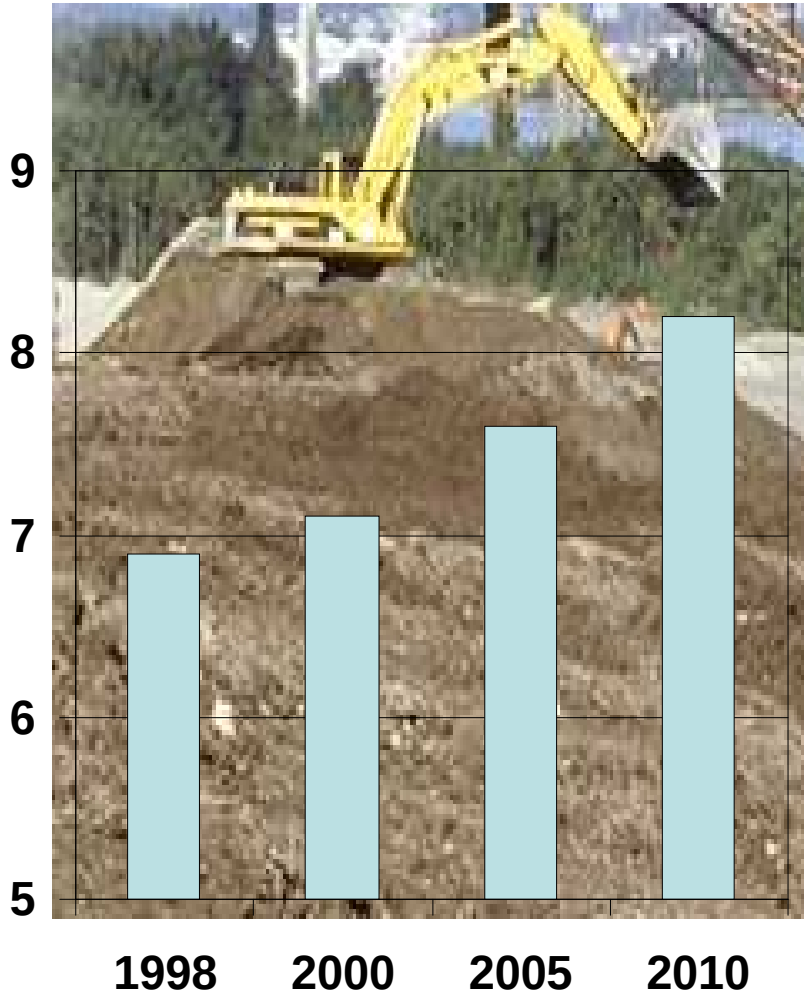
Technical Accomplishments/ Biodiesel from Sewage Sludge (~1 Bgallons oil)

Municipal Wastewater Treatment



Biosolids Generated for Use or Disposal in the United States[1]

- 1998 - 6.9 M dry tons
- 2000 - 7.1 M dry tons
- 2005 - 7.6 M dry tons
- 2010 - 8.2 M dry tons



•1 – "Biosolids Generation, Use, and Disposal in the United States", EPA530-R-99-009, September 1999

Extraction and Transesterification Yield of Waste Activated Sludge[a]

Extraction Medium			% Oil Yield[f]		% of Oil Saponifiable[g]		% Overall Yield[h]	
100% Hexane[b]				1.94		19.7		0.38
100% Methanol[b]				19.39±3.20		14.25±1.66		2.76±0.39
60% Hexane[c]	] – [	Extraction 1	21.20		16.22		3.44	
20% Methanol		Extraction 2	5.37	27.43±0.98	15.57	16.18±3.21	0.84	4.41±0.63
20% Acetone		Extraction 3	0.86		15.92		0.14	
100% Methanol[d]	—	Extraction 1	19.39		14.25		2.76	
100% Hexane	—	Extraction 2	2.57	21.96±2.28	12.03	14.21±1.53	0.31	3.07±0.33
SC-CO_2				3.55		7.87		0.28
SC-CO_2 w/ 1.96 wt% MeOH				4.19		26.8		1.12
SC-CO_2 w/ 13.04 wt% MeOH				13.56		17.0		2.31
In Situ Transesterification[e]				-		-		6.23±0.11

[a]All extractions carried out at 100°C for 1 hour, solvent to solids ratio 40:1
[b]Sample extracted once
[c]Solvent mixture extracted three times
[d]Sequential extraction using Methanol followed by Hexane
[e]Dried to 95 weight percent solids. Solvent was Methanol with 1% Sulfuric Acid
[f]Gravimetric yield of oil in grams of oil per gram of dry sludge
[g]Percent of extracted oil saponifiable on a mass basis.
[h]Grams of FAME produced per 100 grams of dry sludge
[g,h]Values on left indicate individual extraction yields. Values on the right indicate total yield.

Production Cost Estimate for Sludge Biodiesel[a]

Centrifuge O&M	$0.30/lb	$0.43 /gal
Drying O&M		$1.29 /gal
Extraction O&M		$0.34 /gal
Biodiesel Processing O&M		$0.60 /gal
Labor		$0.10 /gal
Insurance		$0.03 /gal
Tax		$0.02 /gal
Depreciation		$0.12 /gal
Capital P&I Service		$0.18 /gal
Total Cost		**$3.11 /gal**

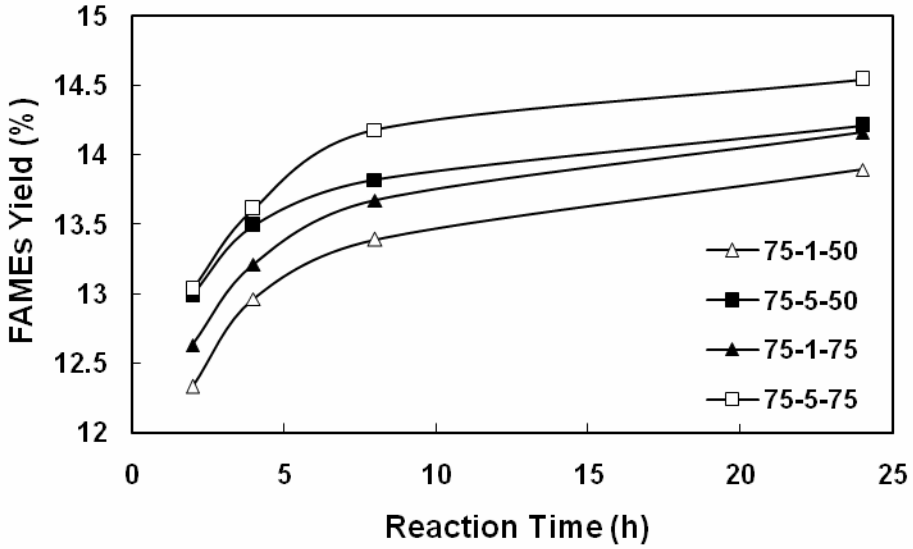
[a]Assuming 7.0% overall transesterification yield

- ✓ Primary and secondary sludge from the Tuscaloosa Wastewater Treatment Facility has been extracted and converted into fatty acid methyl esters (biodiesel)

- ✓ Examination of the various transesterification methods shows that *in situ* conversion of lipids to FAMEs provides the highest overall yield of biodiesel.
- ✓ Assuming at 7.0% overall yield of FAMEs from dry sewage sludge on a weight basis the cost per gallon of biodiesel would be $3.11.
- ✓ As transesterification efficiency increases the cost per gallon drops quickly, hitting $2.01 at 15.0% overall yield.

Biodiesel produced from primary sludge

✓The experimental data indicated that the production of biodiesel by *in-situ* transesterification of primary sludge is second order, when the methanol:lipid molar ratio employed is in great excess compared to the stoichiometric requirement.



Cost per gallc

($)	
Centrifuge O&M	0.22
Drying O&M	0.64
Extraction O&M	0.17
Biodiesel processing O&M	0.60
Labor	0.10
Insurance	0.03
Tax	0.02
Depreciation	0.12
Capital P&I service	0.18
Total cost	**2.08**

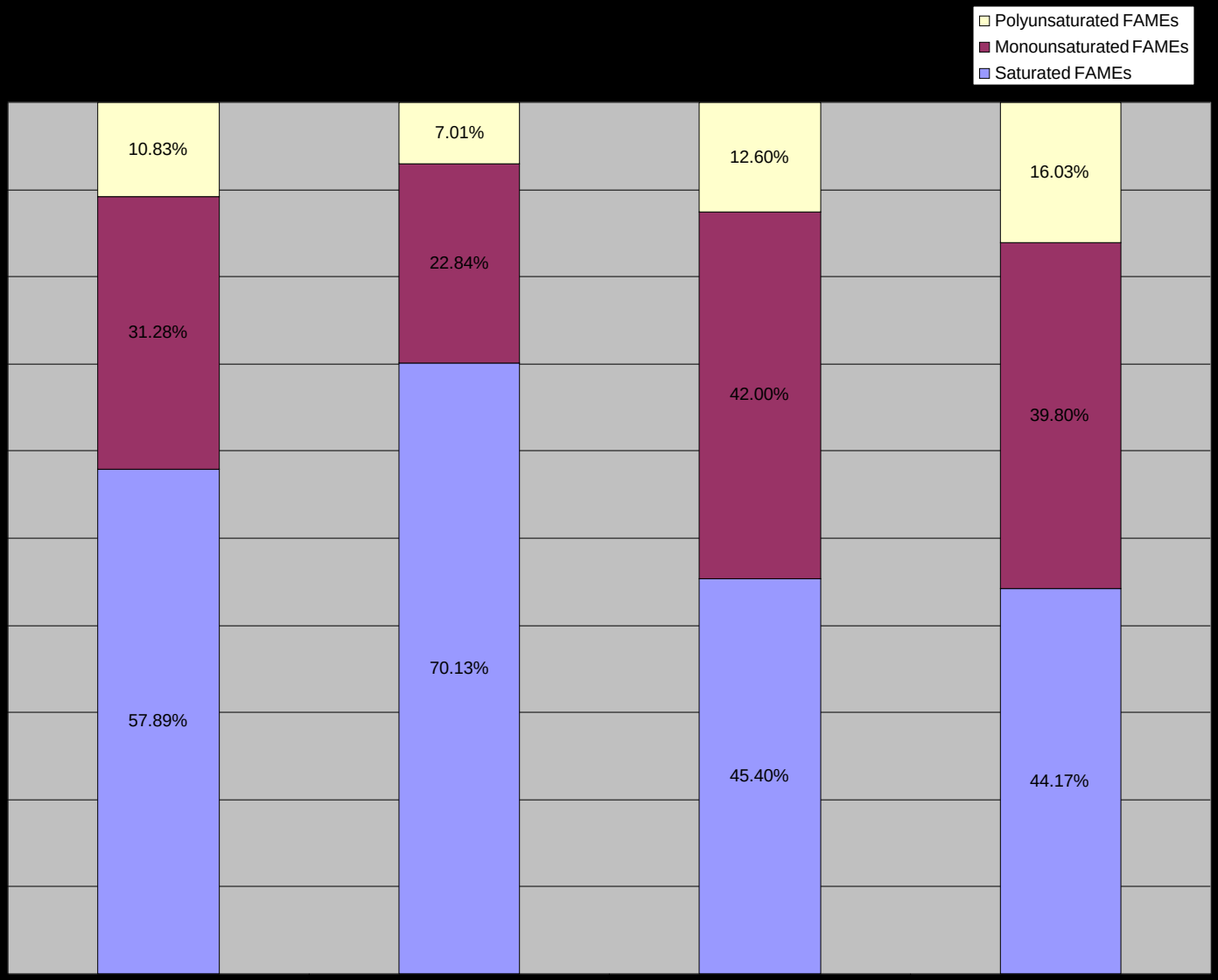
$0.15/lb

✓The biodiesel compositions derived from primary and secondary sludge are indicative of the source of acylglycerides and fatty acids.

✓The cost per gallon of biodiesel from dry primary sludge would be $2.08.

✓This is more cost effective compared to biodiesel from dry secondary sludge.

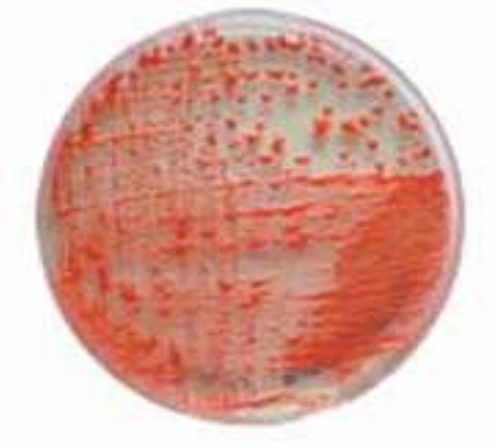
Saturated vs. Unsaturated Distribution in Sludge Sources



The Yeast

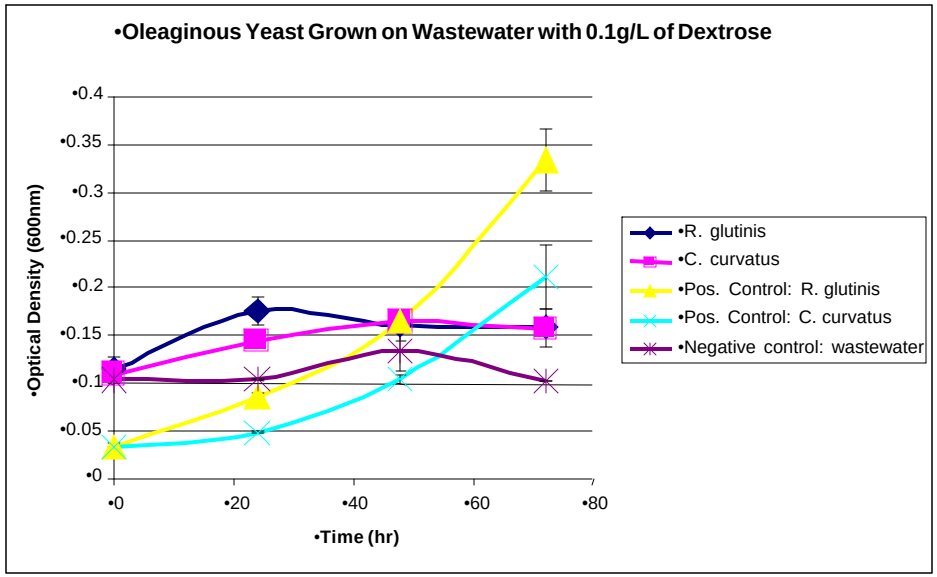
Rhodotorula glutinis

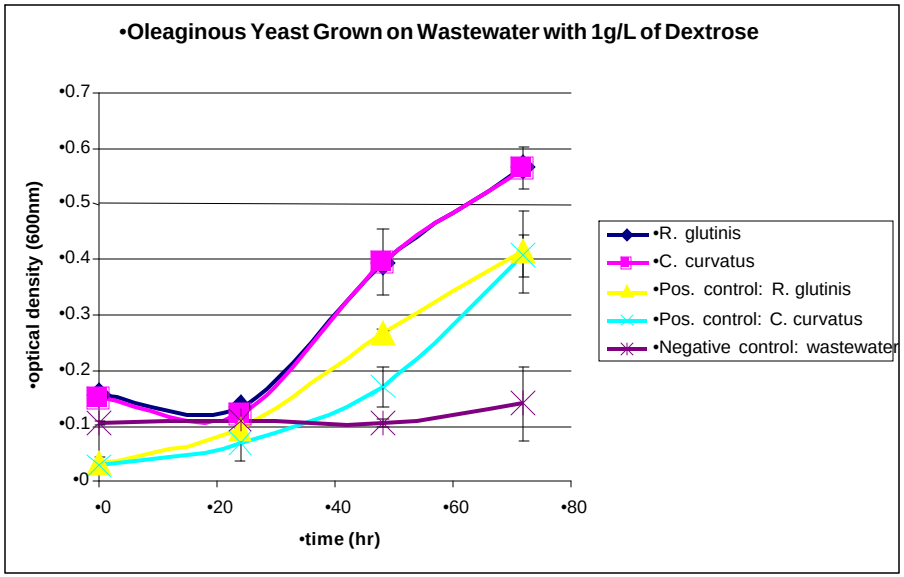
- **Means “red glutton”**
- **Aerobic, oleaginous (oil-producir yeast**
- **High methyl ester yield[1,2]**
- **Breaks down carbon oxygen demand (COD) in waste streams[2,3]**

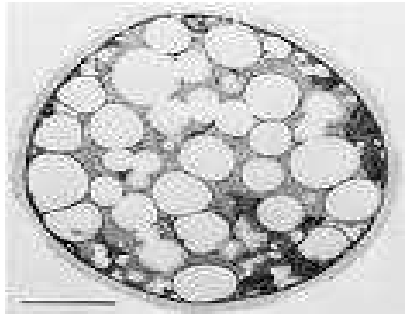


1. Granger, L-M; et al. Biotech. & Bioengineering, 1993, 42, 1151-1156
2. Zheng, S; et al. Bioresource Tech., 2005, 96, 1522-1524
3. Xue, F; et al. Process Biochem., 2006, 41, 1699-1702

Oleaginous Microorganisms Grown on Wastewater

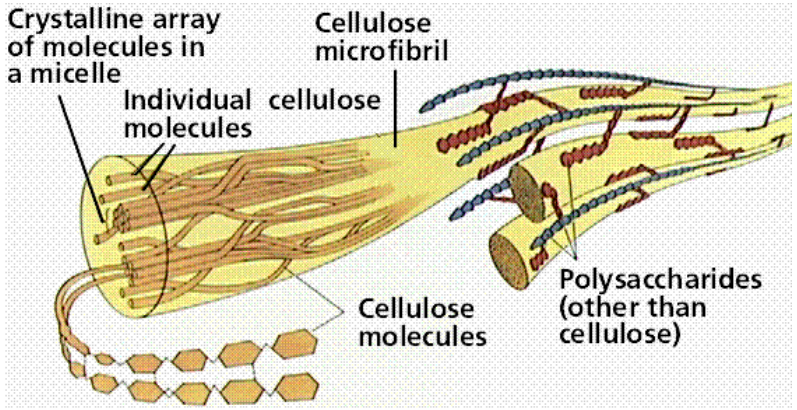




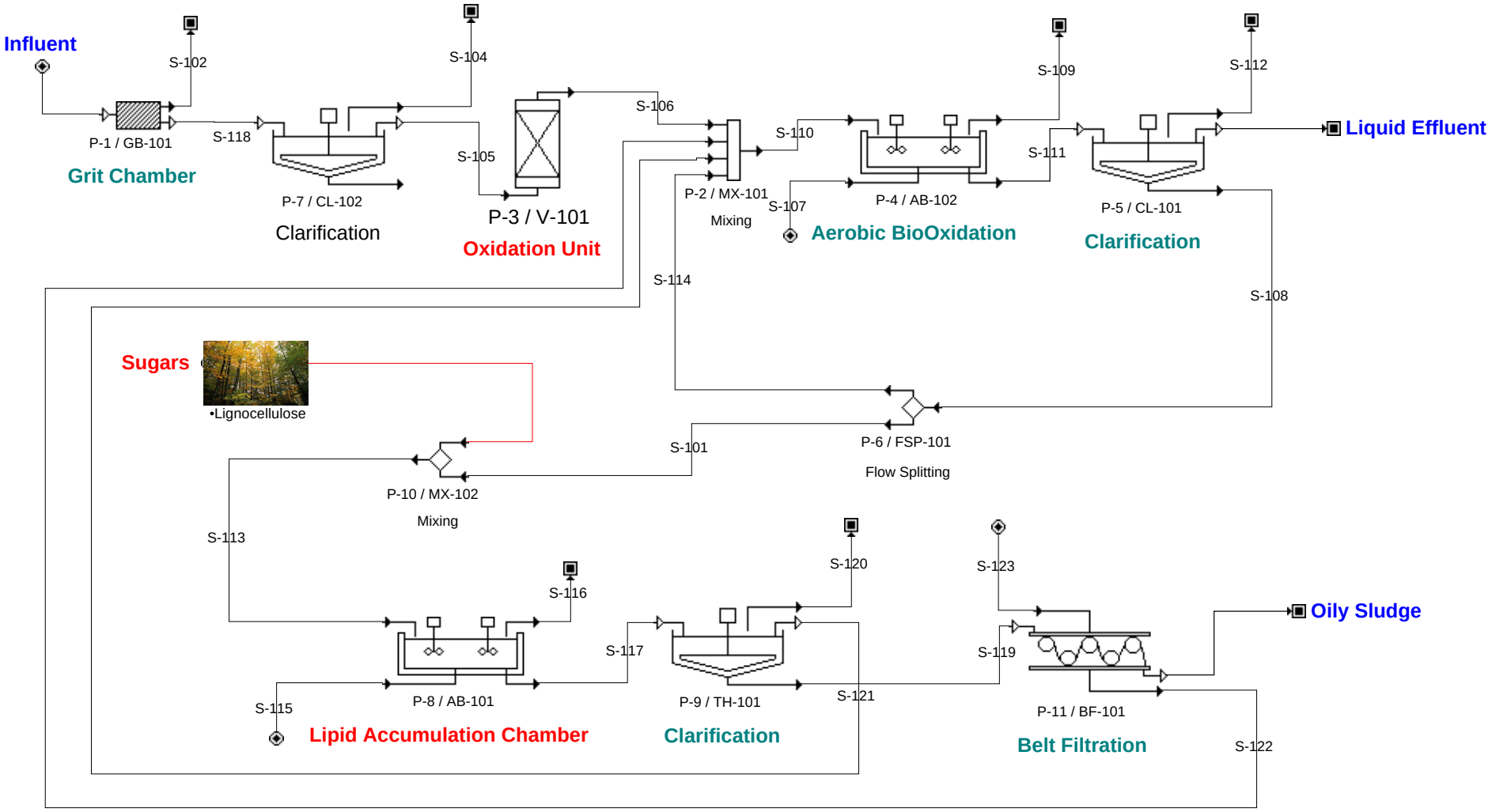


Conversion of Lignocellulosic Biomass to Microbial Oil

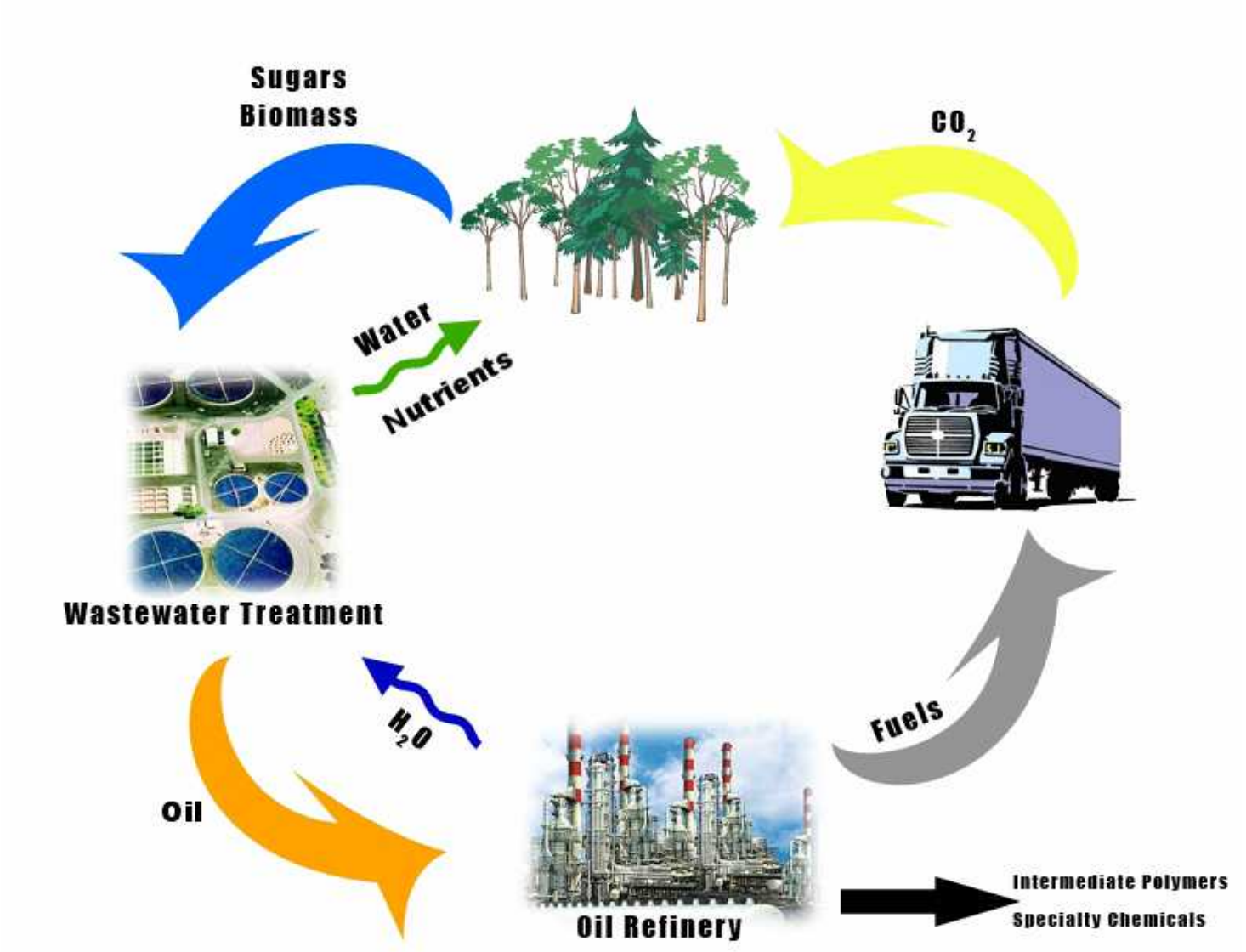
Sugar	Cell mass concentration in culture, mg/ml	Total Lipid production. % dry wt.
artificial acid hydrolysate	4.12	22
Xylose	4.14	30
Dextrose	3.99	35
Switch Grass Hydrolysate	2.63	26

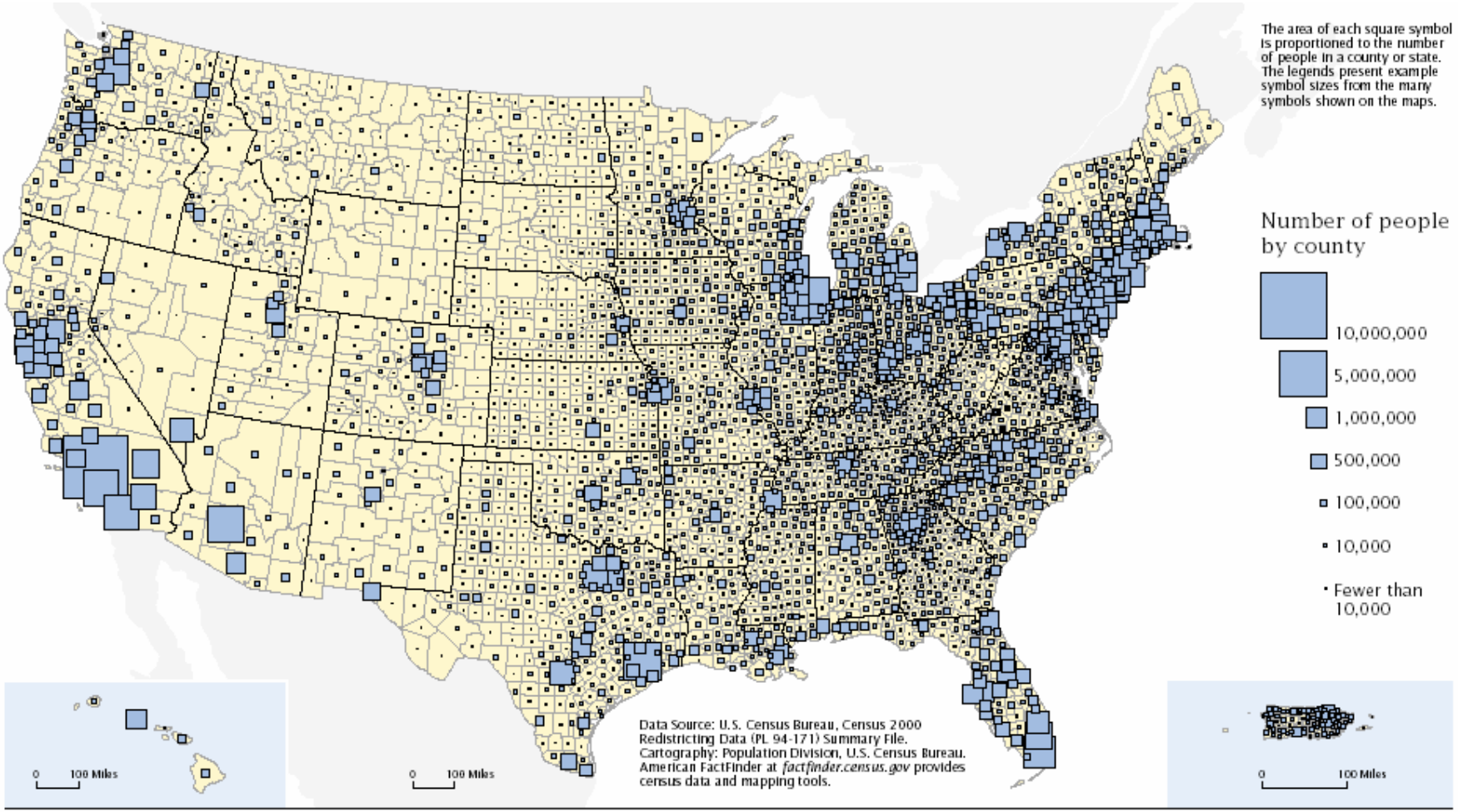


Envisioned Process: The New Biorefineries



Environmentally Sustainable Fuel Production




The area of each square symbol is proportioned to the number of people in a county or state. The legends present example symbol sizes from the many symbols shown on the maps.
Number of people by county
10,000,000
5,000,000
1,000,000
500,000
100,000
10,000
Fewer than 10,000
0 100 Miles
0 100 Miles
0 100 Miles
Data Source: U.S. Census Bureau, Census 2000 Redistricting Data (PL 94-171) Summary File.
Cartography: Population Division, U.S. Census Bureau.
American FactFinder at factfinder.census.gov provides census data and mapping tools.

Benefits…

- ✓ Provides a profitable aspect to sewerage treatment
- ✓ Approximately 30% reduction in biosolids generation (note that biosolids management has become a big problem for cities – disposal costs >$50/dton)
- ✓ Greatly improved pathogen stabilization (Produces Class A Sludge)
- ✓ Minimal impact to on-site treatment operations
- ✓ Minimal additional footprint requirements
- ✓ Provides cheap diesel source to city fleets
- ✓ Adds a fuel production incentive to third world countries to treat sewage

Summary

- **The MSU Biodiesel Project integrates three key research areas associated with biodiesel production: feedstocks, oil extraction, and biodiesel processing technologies.**

- **Although the process for biodiesel production is relatively simple, specific feedstocks may require unique extraction and processing techniques to assure quality.**

- **The Sugar Platform, and current wastewater treatment, biodiesel, and fuel distribution infrastructure could be integrated to potentially generate 10 billion gallons of biodiesel (~10% diesel displacement).**

Acknowledgements

- US Department of Energy
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