DOE BioEnergy Technologies Office (BETO) 2017 Project Peer Review

Algal Polyculture Conversion and Analysis

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Algae Technology Area

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Goal Statement

- Deploy and field test benthic algae production pilot at Corpus Christi and the Salton Sea
- Assess productivity of pilot-scale benthic algae cultivation systems using various source waters
- Demonstrate means for efficient biomass handling and deashing
- Assess techno-economic feasibility and integrated scale-up potential to meet MYPP targets of 5000 GGE/acre @ $3/GGE

Quad Chart Overview

Timeline

- Project start date: March 30, 2015
- Project end date: Sept 30, 2017
- Percent complete: ~85%

Budget

	Total Costs FY 12 – FY 14	FY 15 Costs	FY 16 Costs	Total Planned Funding (FY 17-Project End Date)
DOE Funded		$440K	$950K	$2000K
Project Cost Share (Comp.)*				$150K (IID)

Barriers

- Technical barriers: Algae biomass productivity, Logistics, Conversion

Biomass Availability and Cost (Aft-A)
Sustainable Algae Production (Aft-B)
Overall Integration and Scale-up (Aft-H)
Algal Feedstock Preprocessing (Aft-I)

Partners

- Texas AgriLife, Imperial Valley Conservation Research Center, Imperial Irrigation District, Hydromentia Inc., Prof. Quinn (CSU), ESTECH, Sacred Power Corp.
- Partnering AOPs: Biomass Logistics (1.3.3.100 INL), Protein Conversion (1.3.4.200 SNL)

1 - Project Overview

Algae Turf Scrubber®

e.g., Hydromentia – Vero Beach, Florida

- Polyculture – resilient and resistent to crashes
- Growth: 5-20+ $g/m^2/day$ (AFDW)*
- **No nutrients or external CO_2 added**
- Harvest & dewatering simple, but ash reduction needed
- Requires energy for water pumping to maintain flow
- Polyculture biomass focus - low neutral lipids & higher ash
- Similarities with open field agriculture

VS

Algae Raceway Pond

e.g., NBT – Eilat, Israel

- Monoculture – vulnerable to crashes
- Growth: 5-20+ $g/m^2/day$(AFDW)*
- Needs fertilizer & CO_2
- Harvest & dewatering more difficult & energy-intensive
- Requires energy for water supply and paddle wheel flow/mixing
- Lipid focus (historical)

2 – Approach (Technical)

- Major technical success factors:
  1) *continuous operation in austere environments & variable environmental conditions*
  2) *robust biomass productivity with low cost means for ash reduction*
  3) *technoeconomic feasibility and scale-up potential*

- Technical Challenges
  1) *prevent single-mode of failure operations for unmonitored systems*
  2) *simple, low cost field harvesting and dewatering process*
  3) *efficient ash removal from high suspended solids content source waters*

- Approach
  1) *Deploy algae turf systems (ATS) at locations with distinct source-waters to evaluate productivity and compositional variance*
  2) *Provide seasonal biomass samples to partnering projects for evaluation of biomass logistics, pre-processing, and fuels conversion*
  3) *Perform technoeconomic, resource, geographic information assessments for scale-up potential*

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2 – Approach (Management)

- **Focus on critical success factors that will define technical and commercial viability**
  - Credible path and progress toward meeting MYPP algal production scale-up & cost targets.
  - Industry and other partnerships for improvement of polyculture biomass production & scale-up (e.g., HydroMentia, Texas AgriLife, Imperial Irrigation District, ESTECH, others)

- **Project Milestones and Go/No-Go criteria emphasis on biomass productivity and path toward affordable scale-up**
  - **Go/No-Go**: Demonstrate benthic algal polyculture turf productivity (annual average) of 20 g m^{-2} d^{-1} (AFDW)
  - Demonstrate path and feasibility of scale-up via TEA and resource assessment
  - Comparative testing and evaluation of polyculture vs. monoculture for fuels
  - Coordinate/collaborate with other BETO labs and academic institutions

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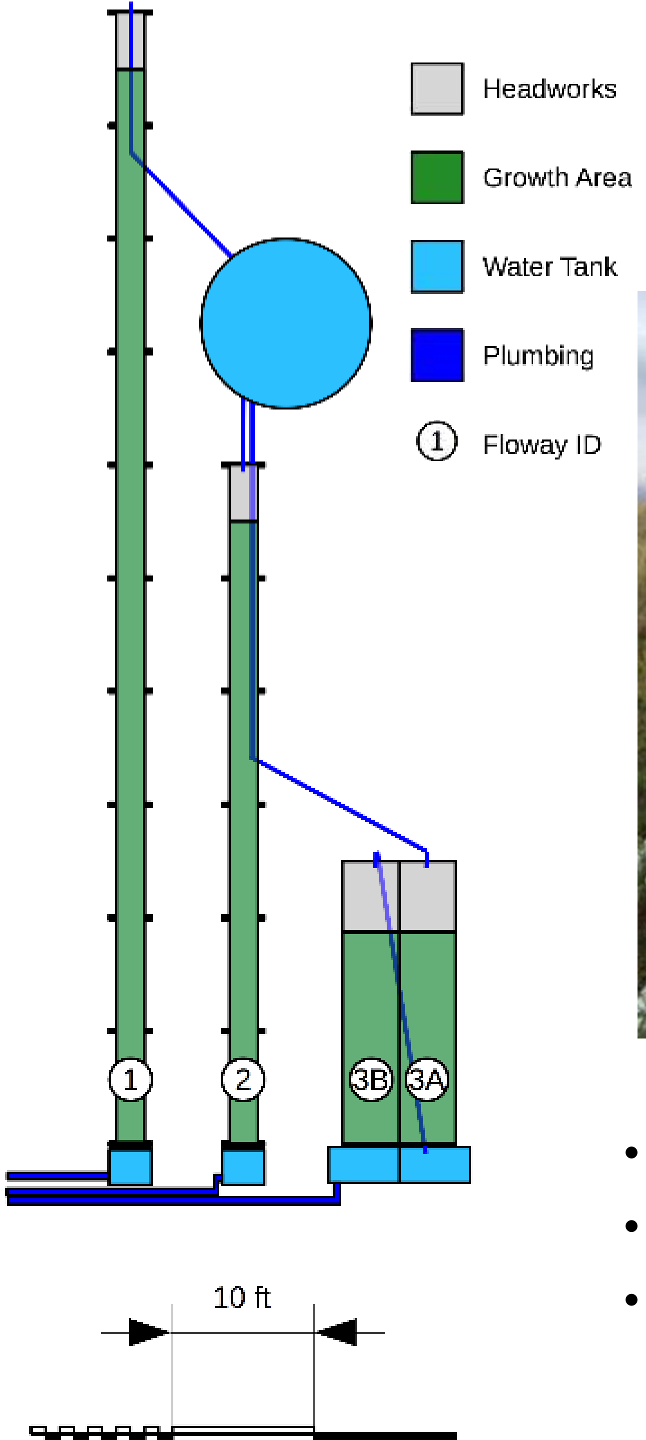
3 – Technical Accomplishments/ Progress/Results

Deployment 1: Texas AgriLife, Corpus Christi

Small white circles outline regions expanded in subsequent panels. **(A)** Situation of Corpus Christi, TX wrt Gulf of Mexico. **(B)** Power plant site, showing freshwater reservoir to the left and marine water intake canal to the right. **(C)** AgriLife research facility wrt the reservoir and canal. **(D)** Pumping station (shared with Texas Fish & Wildlife) for withdrawing marine water. **(E)** AgriLIFE research facility wrt to holding ponds and location (green bar) of ATS floways. **(F)** View of marine water pumping facility from red circle in panel D.

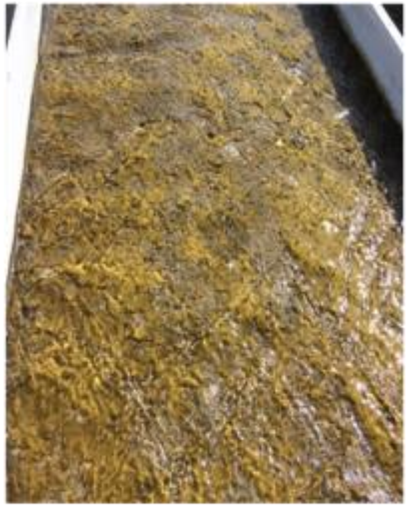
ATS System Layout at TAMU-CC Flour Bluff



- **Floway 1** - 2 feet wide x 80 feet long
- **Floway 2** – 2 feet wide x 48 feet long
- **Floway 3A and 3B** - 4 feet wide x 20 feet long (with 5 feet covered by dump buckets) – 15 feet active

ATS Biomass Production at Texas AgriLife, Corpus Christi

- Stably operating since May, 2016
- Initially populated by modest productivity pioneer turf
- Rapid population shift to stable, high productivity filamentous green alga following pioneer phase
- >60 Kg biomass delivered to characterization, logistics, and processing teams



Pioneer algal turf (benthic diatoms) →

Established algal turf (*Cheatomorpha*) →

Weekly harvest (low cost) →

Biomass!

Initial multi-month algal turf productivity 7 ± 2 g m^2 day^{-1}

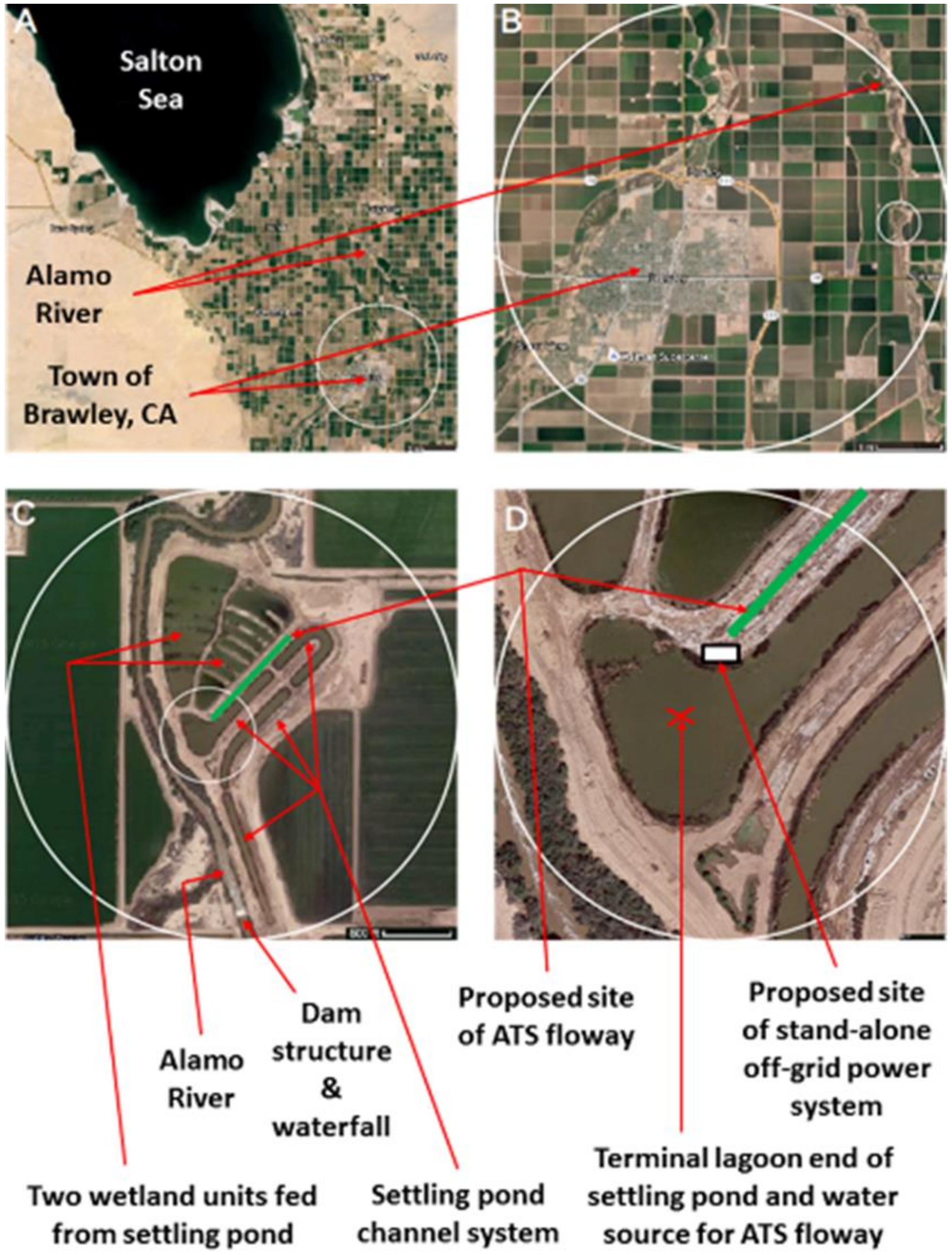
Systematic optimization of harvest schedule, flow rates, and substrate currently underway

Field Dewatering @TexasAgriLIFE

- Simple, screen-based dewatering strategy for standardization at various production sites
- Fine filament size pioneer cultures were dewatered to ~13% solids in under 1 hour with negligible biomass losses
- Apparatus and protocol has been duplicated for use at Salton Sea installation

Salton Sea: Shank Road Wetland Site

Small white circles outline regions expanded in subsequent panels. (A) Location of Brawley, CA wrt southern part of Salton Sea. (B) Location of Shank Road Wetlands wrt to Brawley. (C) Wetlands area and adjacent site for ATS floway. Water from the Alamo River enters from the south, upstream of a dam structure, and flows by gravity through the serpentine settling pond and wetland. (D) Tail of the final settling pond (Terminal lagoon), which is the planned water withdrawal source for the pilot scale ATS floway.



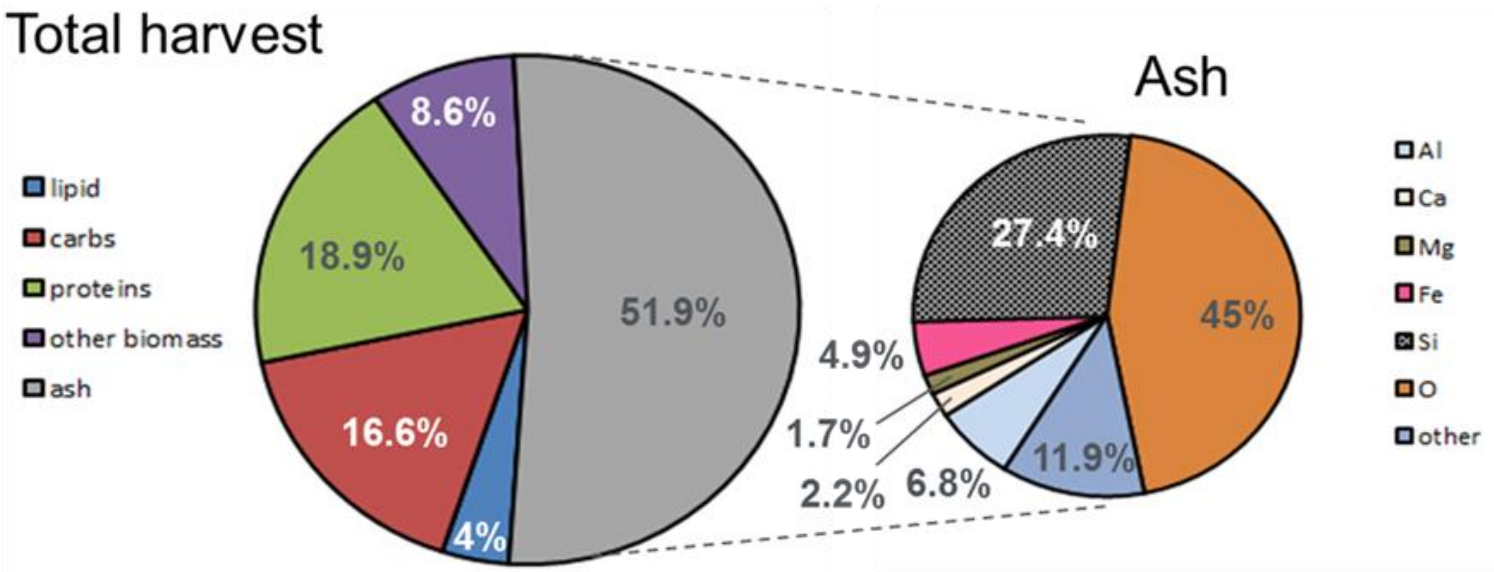
ATS System Deployment, Brawley-IVCRC

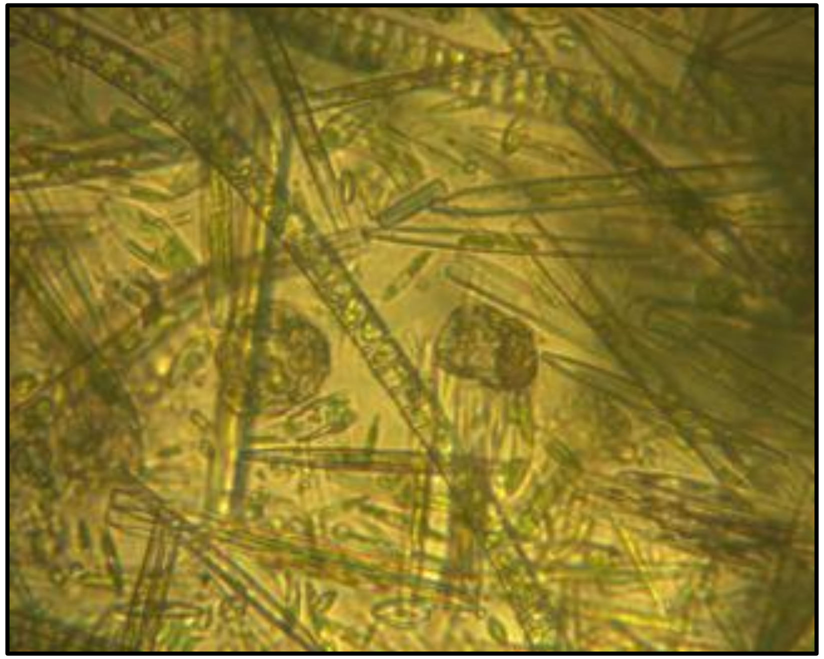
- Site encroachment cost-match provided by the CA Imperial Irrigation District near Brawley, CA on tributary to Salton Sea
- State of California interested in bioremediation potential of ATS to prevent heavy metals (esp. Se) accumulation in wetlands fauna
- Austere site: no physical security or facilities, pumping provided by renewable power pumping
- Source water: 95% agriculture runoff

Algal turf biomass characterization

* Systems non-optimized for increased AFDW biomass w/ reduced ash

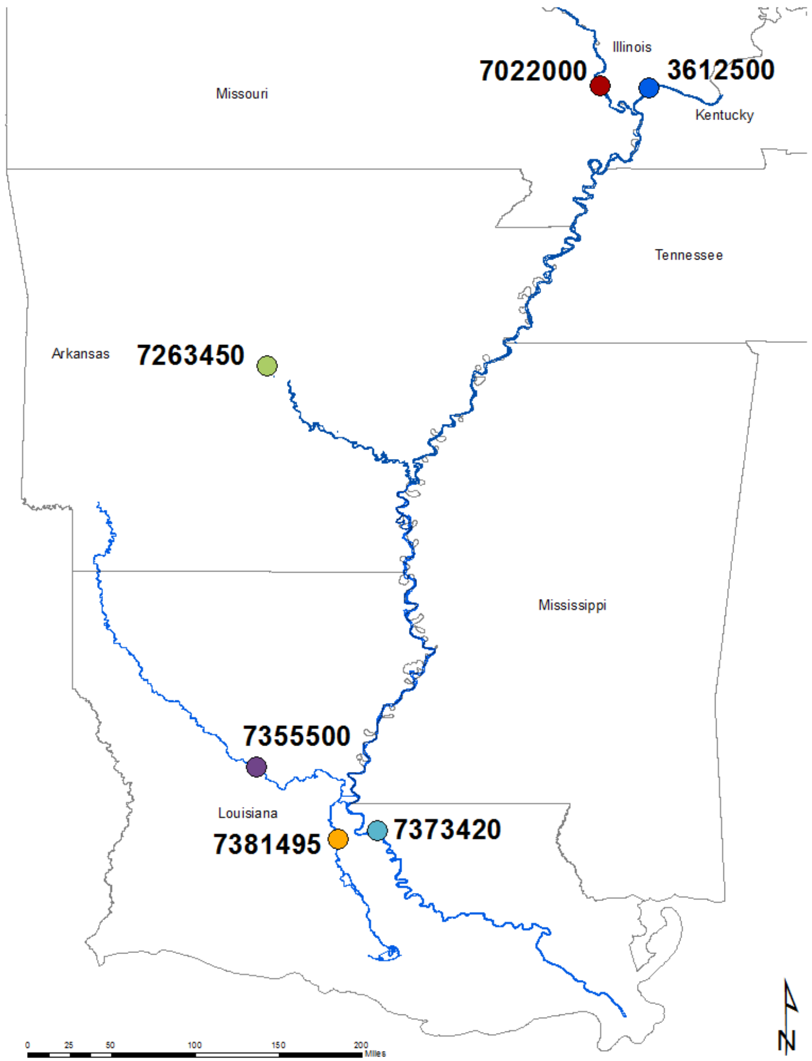
- Variable composition: dependent on water source, climate, and season
- Composed of multiple phylogenetic groups: dominant clades include chlorophyta, diatoms, and cyanobacteria
- Low lipid content
- Biogenic and non-biogenic ash content
- ATS cultivation & harvest system not optimized for lower ash



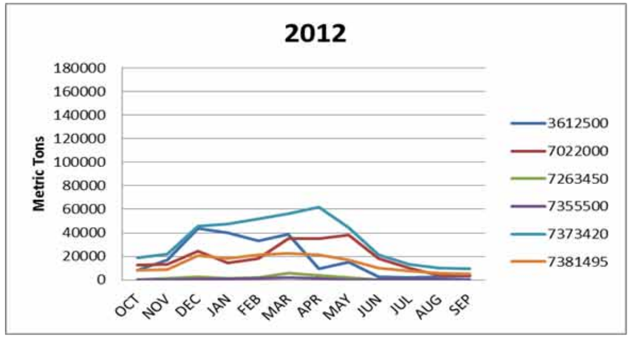


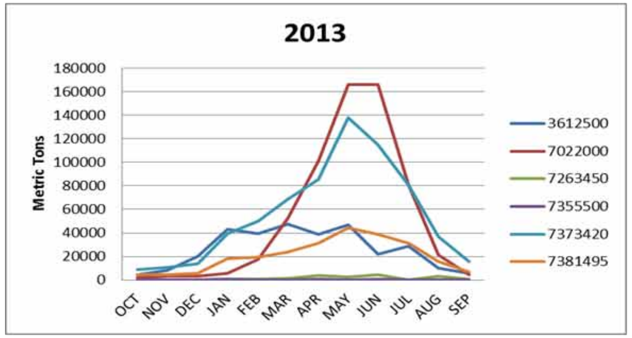
HydroMentia Biomass,
Fresh source water:
Agriculture/storm runoff

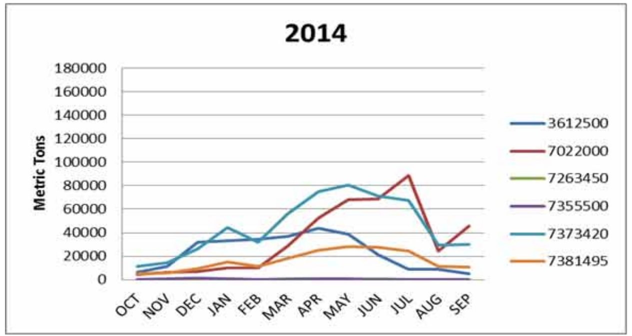
Initial Look at N and P Flux
in Lower Mississippi River Watershed



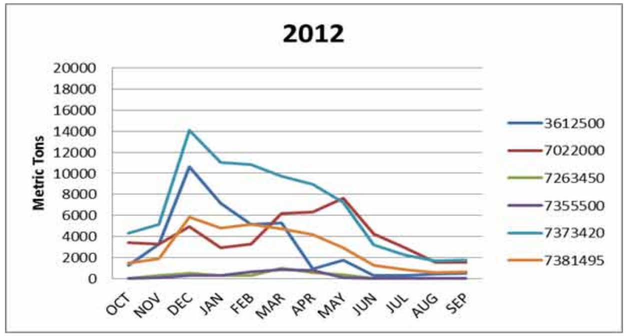
Nitrite and Nitrate

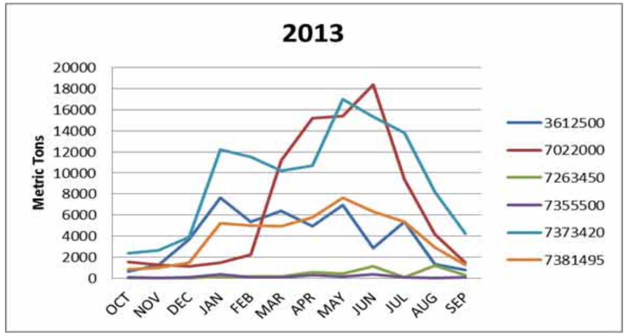


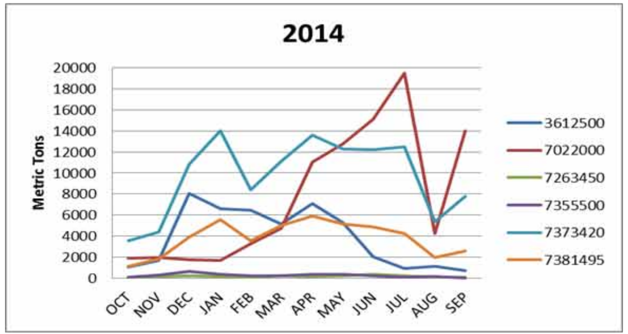




Phosphorous







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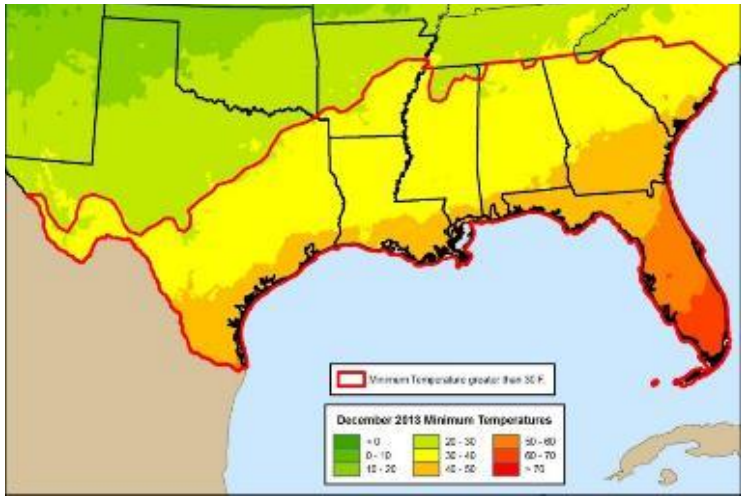
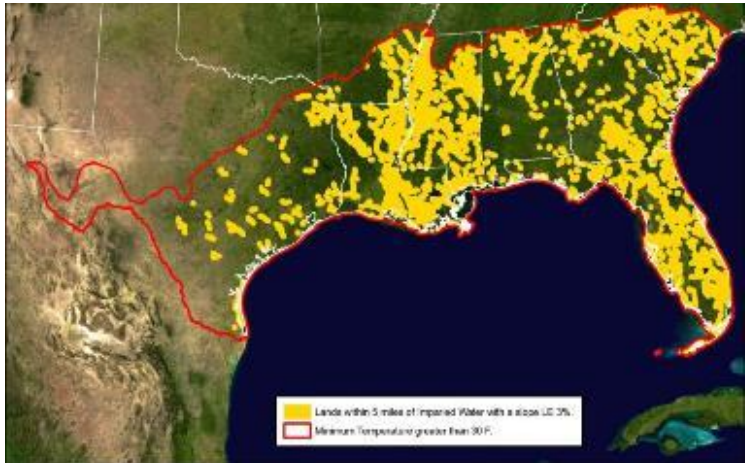
Promising Potential for ATS Based Fuel Scale-Up in Southeastern States Region

Dual-use: algal biomass feedstock production & water quality improvement

Region with coldest monthly temperatures > 30° F



Potentially suitable land areas for deployment of ATS within 5 miles of impaired streams and other inland water bodies



Possible Scale-Up Potential > *1 billion GGE/yr ...*

Based on initial screening of potentially suitable land area for siting Algal Turf cultivation closely adjacent to impaired surface waters in the eight state Southeastern region with minimum monthly temperatures > 30˚ F

Scenario: Use 9% of the identified shrubland acreage and achieve annual average algal turf biomass productivity to give fuel yield of ≥ 2000 GGE/acre

State	Ag Acres within 5 miles of Impaired Waters	Shrubland Acres within 5 miles of Impaired Waters	Total Ag & Shrubland Acres within 5 miles of Impared Waters
Alabama	2,312,215	388,264	2,700,479
Arkansas	1,705,378	78,175	1,783,553
Florida	6,621,383	876,168	7,497,551
Georgia	3,004,481	445,032	3,449,513
Louisiana	9,865,027	639,112	10,504,139
Mississippi	9,702,977	1,609,786	11,312,763
South Carolina	3,041,534	481,329	3,522,863
Texas	3,797,384	1,078,400	4,875,784
Total Acres	40,050,379	5,596,266	45,646,645

Data sources used:

Temperature Data from PRISM Climate Group, Oregon State Univ. - http://www.prism.oregonstate.edu/

Impaired Streams and Water bodies from the EPA ATTAINS Program - http://water.epa.gov/scitech/datait/tools/waters/data/downloads.cfm

Digital Elevation Model (GTOPO30) from the USGS - https://lta.cr.usgs.gov/GTOPO30

4 – Relevance

- Use and improvement of ATS cultivation and harvesting for biofuel feedstock production leverages industry commercialization of the technology for water treatment, provides dual-use opportunity for possible environmental service credits, and can avoid cost and logistics of providing supplemental CO_2 and nutrients

- Leveraging polyculture algal turf biomass productivity, stability, and resilience, and achieving high biochemical and HTL processing efficiencies in converting all biomass components (proteins, carbohydrates, lipids, other) to fuels are key to meeting MYPP goals

- Preliminary TEA feasibility results for bio and thermochemical processing of whole wet algal turf biomass are promising for identifying path to meet cost targets

- Preliminary land and impaired water source screening assessment results show promise for siting single-pass ATS operations sufficient for U.S. production scale-up required to help meet MYPP goals and milestones.

Publications, Patents, Presentations, Awards, and Commercialization

- SNL Patent Application (SD#131107) – "Tandem Bio- and Thermo-chemical Conversion of Mixed Algal Biomass" Ryan W Davis, Anthe George, Todd W Lane, Ronald C Pate, Ben C Wu.
- Hoffman J, Pate RC, Drennen T, Quinn JC "Technoeconomic assessment of open microalgae production systems" Algal Res (accepted Jan, 2017)
- Presentations at 2014-2016 ABBB Symposium and 2014-2016 ABO Summits.
- Interest, cost-match by the State of California for ATS deployment at Salton Sea
- Collaboration on Algal Turf Scrubber cultivation & harvesting with Walter Adey (Smithsonian Institution) and HydroMentia
- Collaboration discussions with ATP3 re/ testing of polyculture vs. monoculture , LBNL-ABPDU and PNNL re/ larger scale polyculture biomass biochemical and HTL processing, and others in industry re/ commercialization.