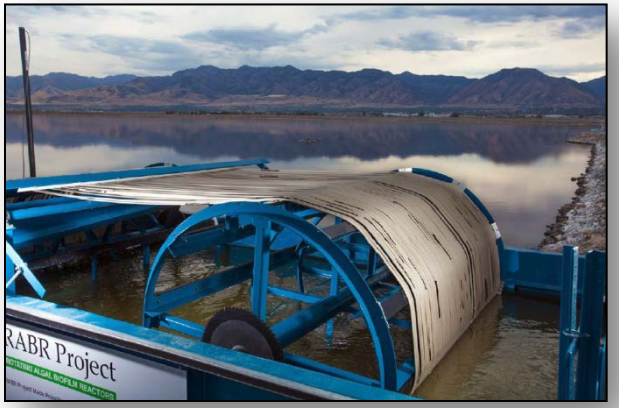
Sustainable Waste-to-Bioproduct Engineering Center (SWBEC)

The Sustainable Waste-to-Bioproduct Engineering Center converts society's wastes into valuable products to promote national energy independence, local production of bioproducts, new industries for new jobs, and protection of human health and the environment. (2 years old)



Algae Biofilm Growth

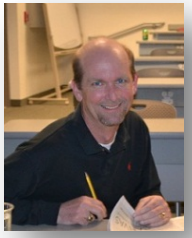
Logan Lagoons

Algae to Biodiesel

SWBEC Affiliated Faculty & Staff

Ron Sims
-BE -
Co-Director

Issa Hamud
-BE & Logan City-
Co-Director



Charlie Miller
- BE -

Jon Takemoto
- Biology -

Byard Wood
- MAE -

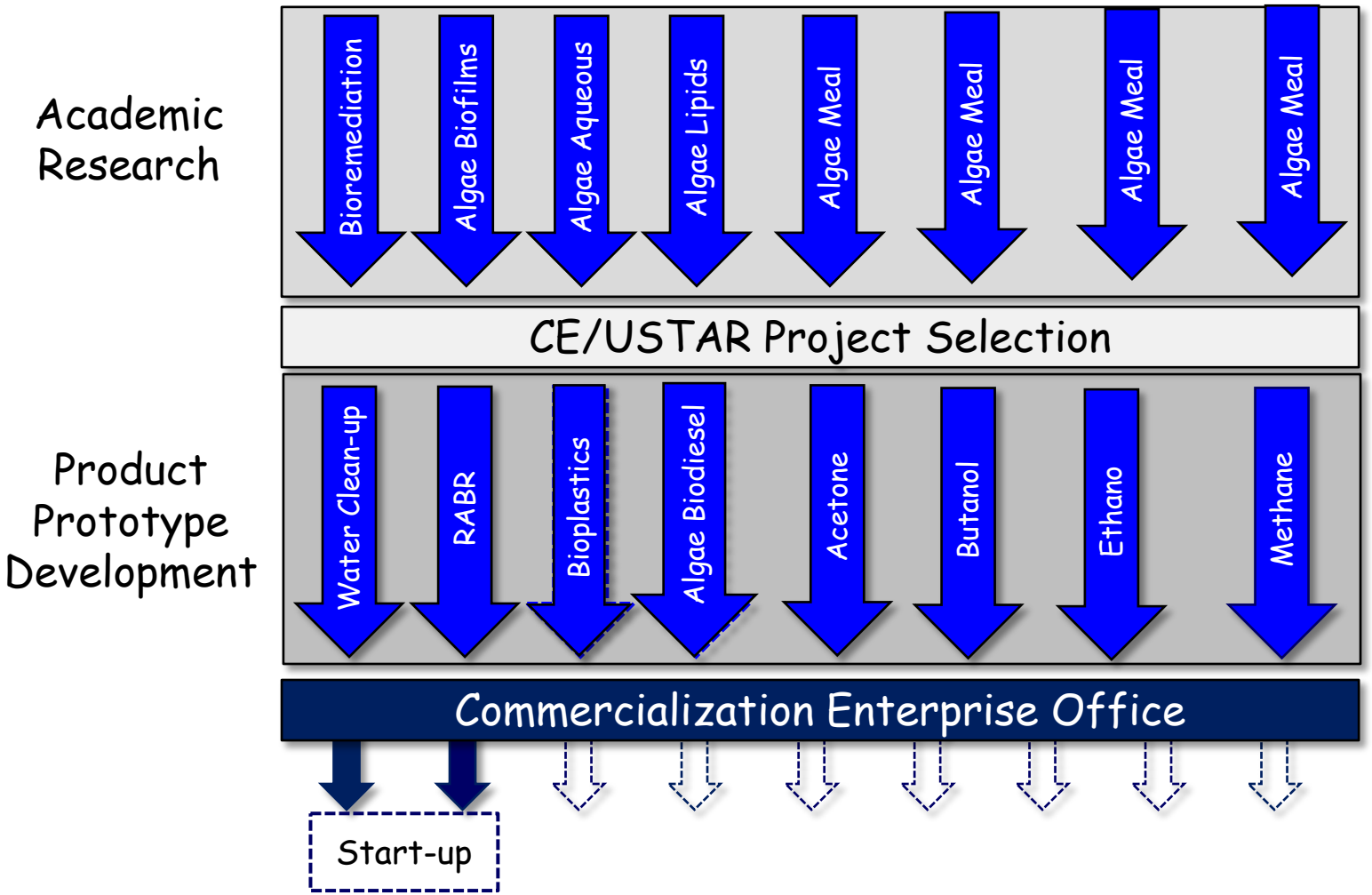
Reese Thompson
Research Engineer

Ashik Sathish
Research Engineer

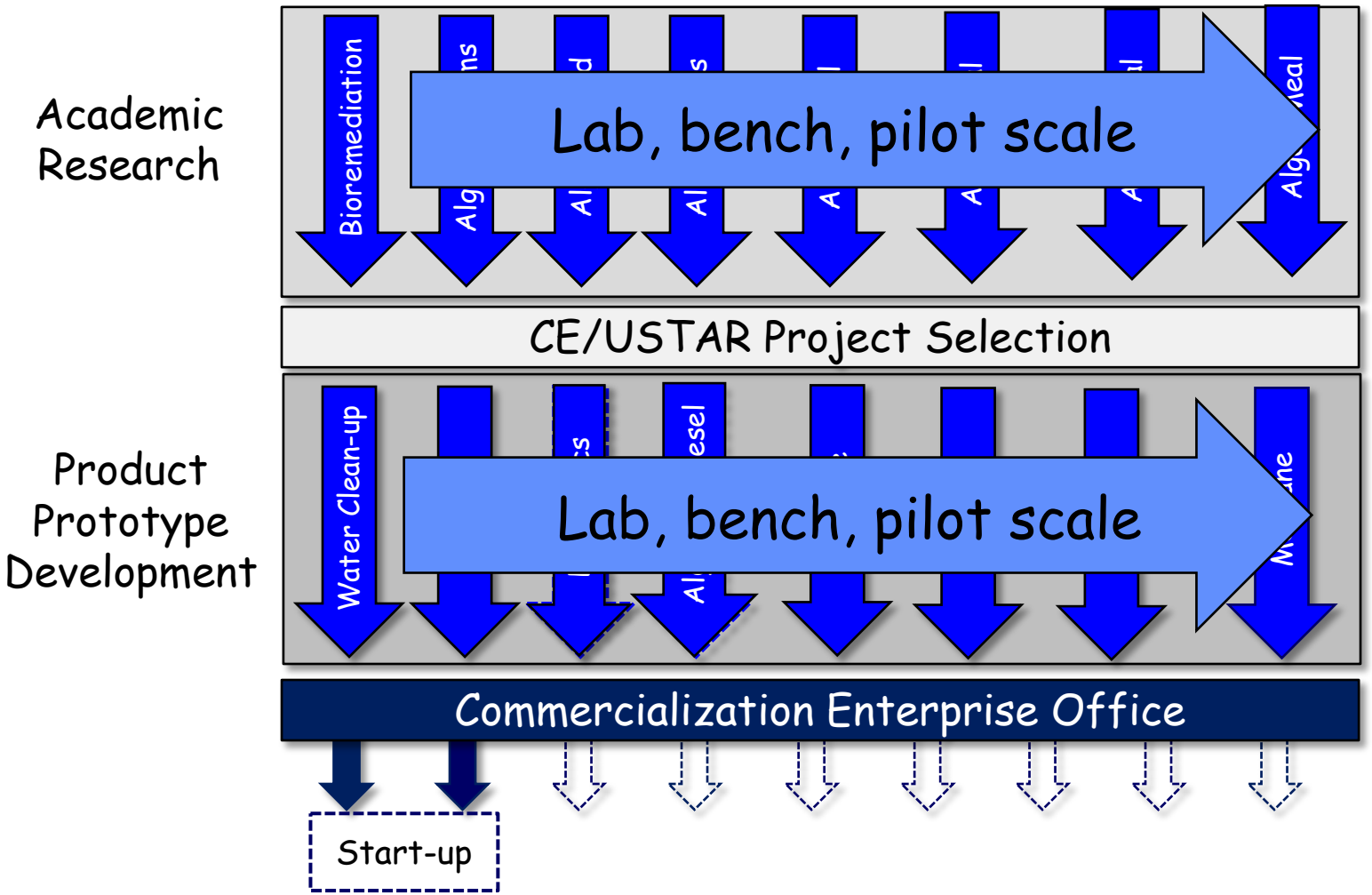
Number of funded students – ~20 (9G/11UG)

Number of funded staff - 2

Current SWBEC Project Pathways



Current SWBEC Project Pathways



Patent Activity

1. Methods for Producing Acetone, Butanol, and Ethanol (ABE) from Algae Biomass Produced from Wastewater. 2012. Non-Provisional Patent Application number 61/552,317.

1. Methods of Harvesting Biomass. 2012. Provision Patent Application Number 61/552,604.

3. Method of Lipid Extraction. 2012. Non-Provisional Patent Application Number 61/551,049.

4. Methods for Bioplastic Production. 2012. Provisional Patent Application Number 61/657,649.

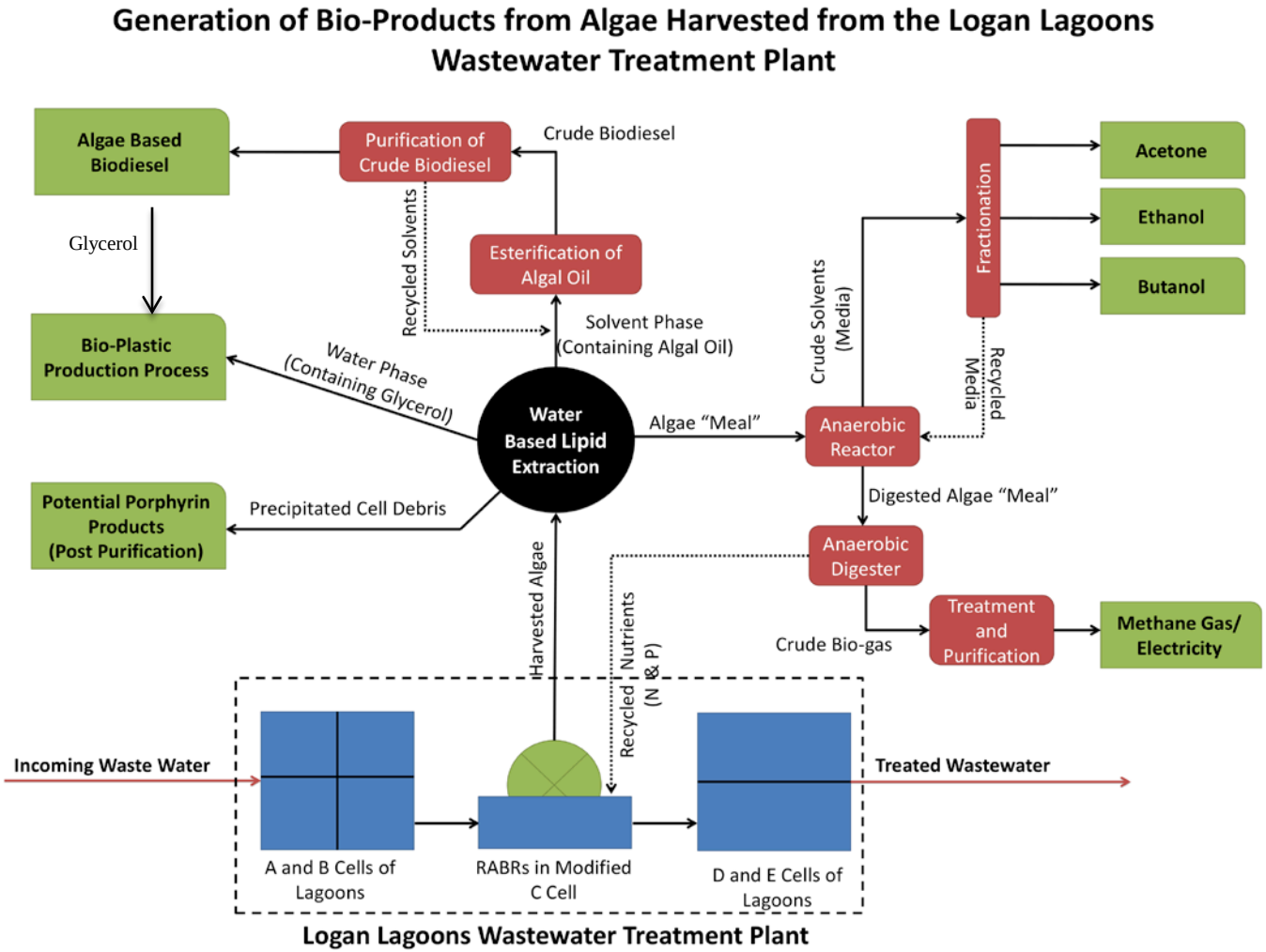
5. Biomass Production Using a Rotating Bioreactor and Spool Harvester. 2010. Provisional Patent Application Number 61/310,360. Utility patent submitted 2011.

6. A Novel Use of Phasin Protein for Purification of Polyhydroxyalklanoates. 2009. U.S. Patent Application 20110159555.

Publications

1. **Bioremediation** of domestic wastewater and production of bioproducts from microalgae using waste stabilization ponds. 2012.
2. **Rotating algal biofilm reactor** and spool harvester for wastewater treatment with biofuels by-products. 2012.
3. **Acetone, butanol, and ethanol** production from wastewater algae. 2012.
4. **Polyhydroxybutyrate** quantification in organic wastes and pure cultures using a single-step extraction and 1H NMR analysis. 2012.
5. **Biodiesel** from, mixed culture algae via a wet lipid extraction procedure. 2012.
6. Metagenome analysis of a methanogenic community within an algal fed **anaerobic digester**. 2012.
7. Monitoring microbial diversity of bioreactors using metagenomic approaches. 2012.
8. Production and harvesting of microalgae for **wastewater treatment, biofuels, and bioproducts**. 2011.

Research to Prototype

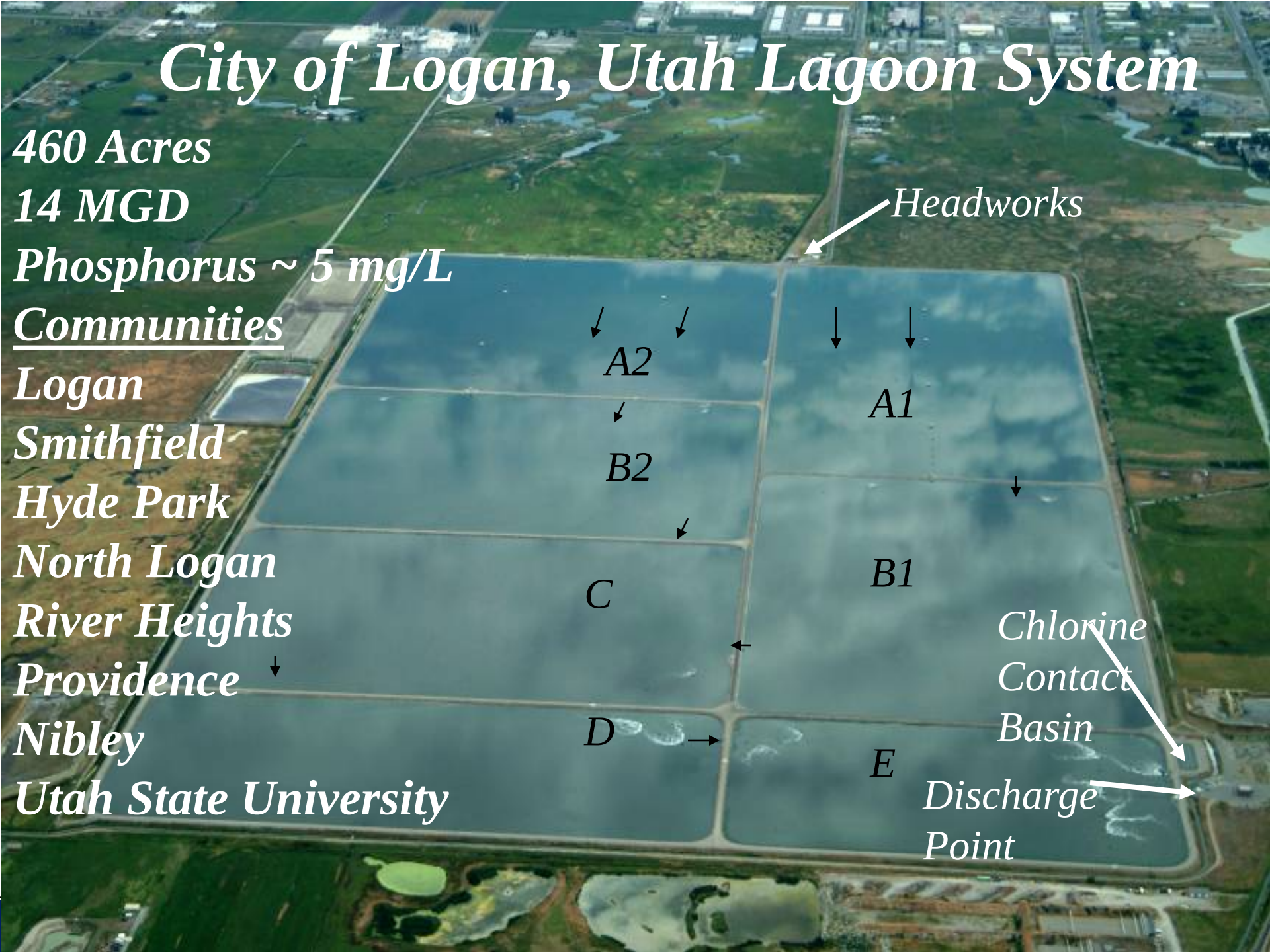


Algae Farming for Nutrient Removal and Bioproduct Production

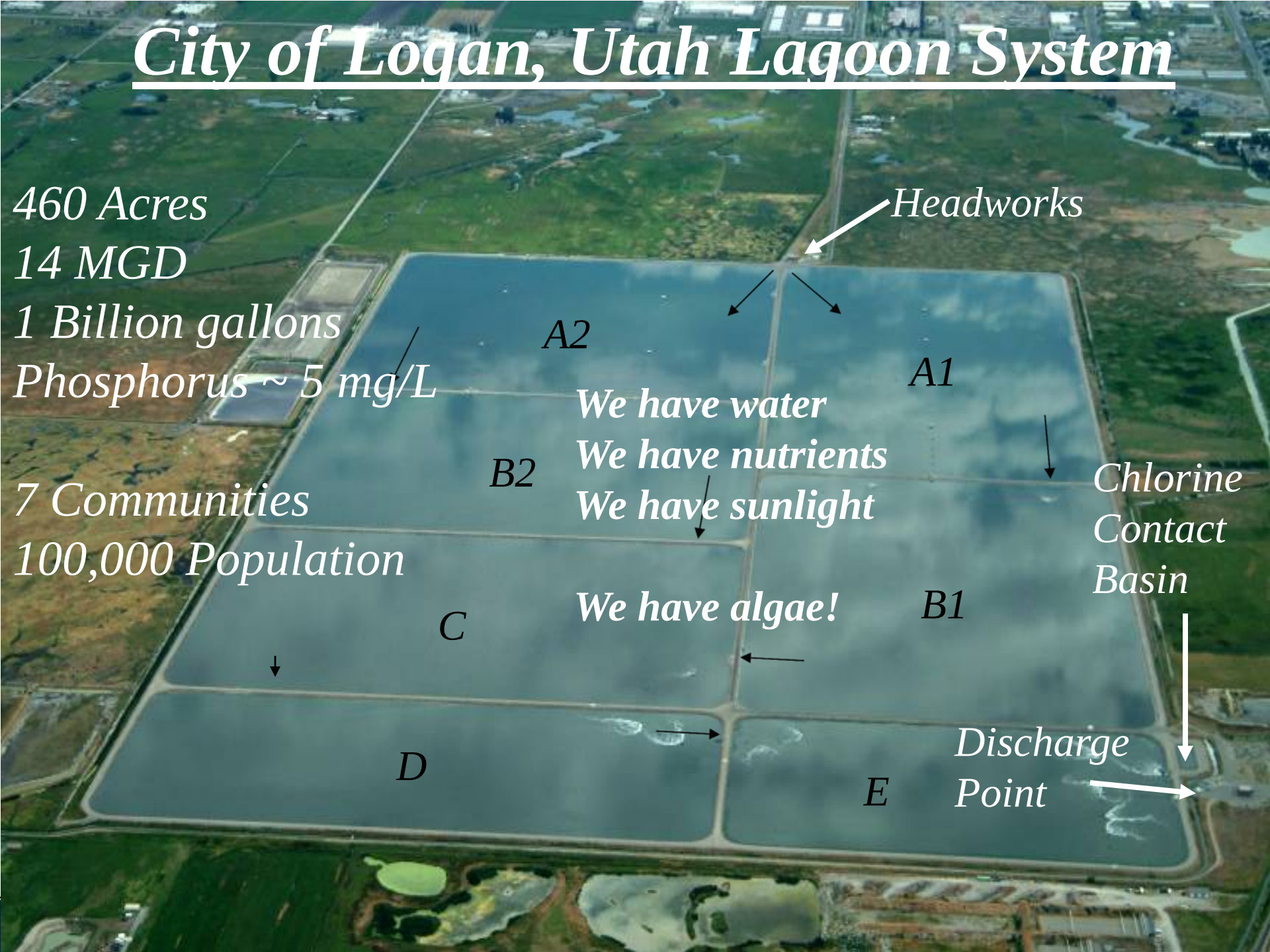
- Nutrient removal – phosphorus and nitrogen through production of algae biomass for wastewater bioremediation

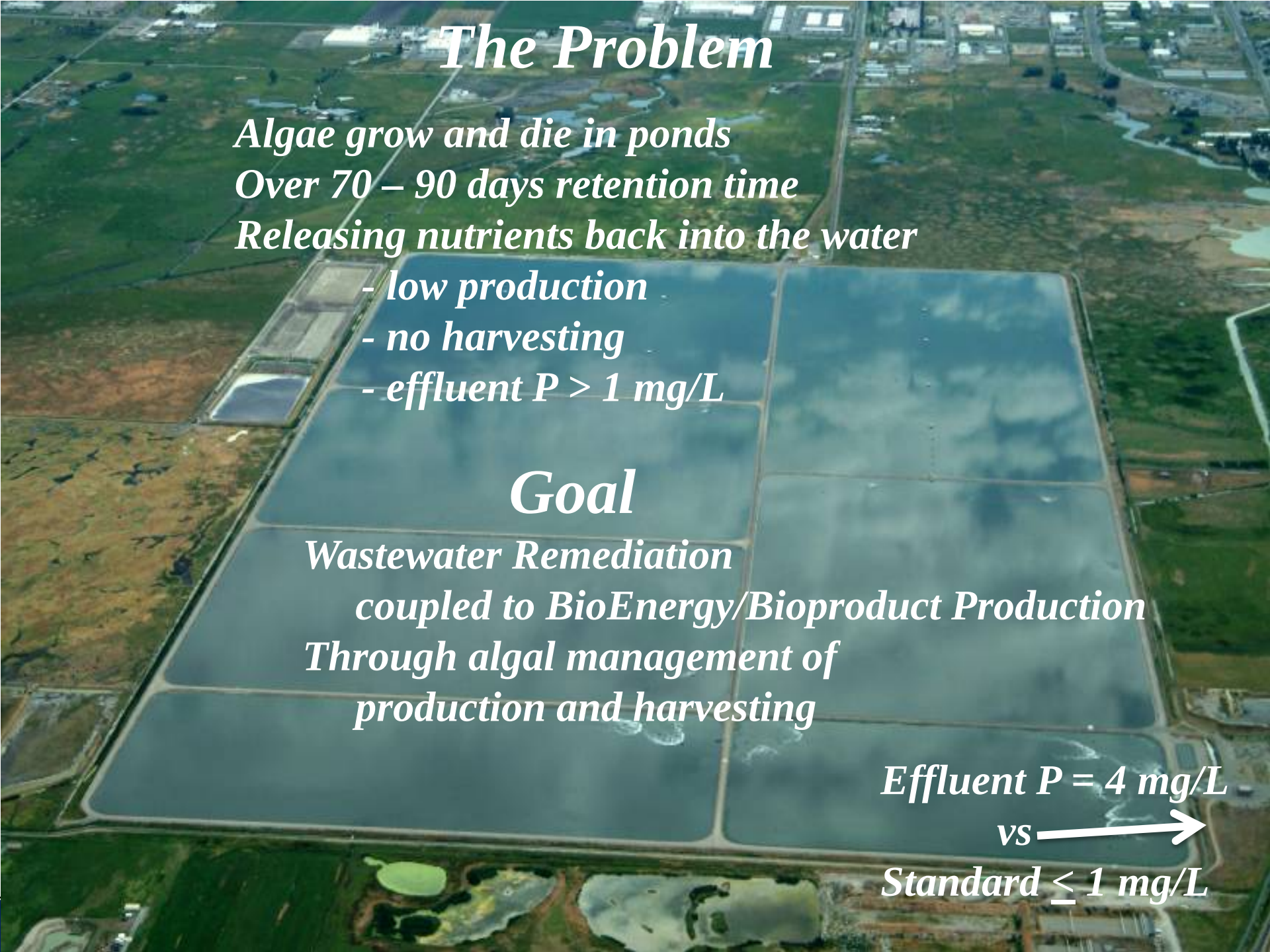
- Cultivate and Harvest algae biomass and transform to biofuels and bioproducts

City of Logan, Utah Lagoon System



City of Logan, Utah Lagoon System





The Problem

Algae grow and die in ponds
Over 70 – 90 days retention time
Releasing nutrients back into the water
- low production
- no harvesting
- effluent P > 1 mg/L

Goal

Wastewater Remediation
coupled to BioEnergy/Bioproduct Production
Through algal management of
production and harvesting

Effluent P = 4 mg/L
vs →
Standard ≤ 1 mg/L

Objectives

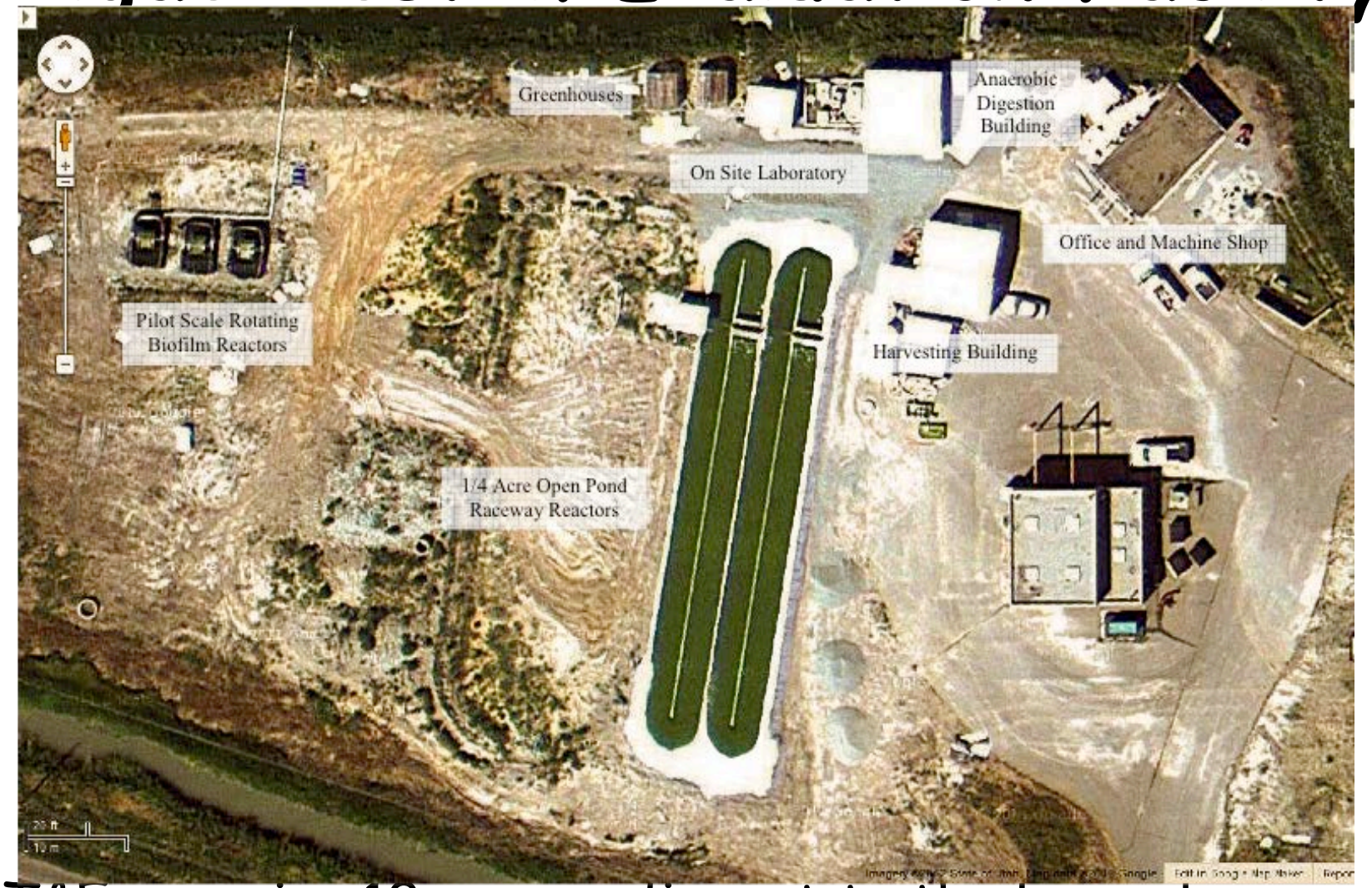
1. *Treat wastewater to meet standard (1 mg/L P)*
2. *Develop algae biomass production methods*
3. *Develop algae harvesting methods*
4. *React algae to produce biofuels & bioproducts*

USTAR Turning innovation into industry.

SWBEC Sustainable Waste-to-Bioproducts Engineering Center

Utah State University SYNTHETIC BIOMANUFACTURING INSTITUTE

Algae Test & Evaluation Facility



AT&E occupies 10 acres adjacent to the Logan Lagoons

Rotating Algal Biofilm Reactor (RABR)

- Combine biomass production and harvesting
- Eliminate need for DAF, Centrifugation (energy) to separate algae from water
- Harvest-scraping
- Nutrient bioremediation

- Provisional Patent No. 61310360 (3/4/2010).
- Utility patent application submitted 2011. (Logan Christenson and R.C.S)

RABR Strategies

- Independent of Water Color or Turbidity
- Suitable for Deeper Water (than Raceways)
- Suitable for "Drop In" Retrofit for Ponds, Lagoons
- Suitable for "Add On" Retrofit (Plug and Play)

Biomethane from Algae

- Two 1,000 gallon Anaerobic Digesters
- Mix algae with solid waste to generate more methane

Algae Processing and Products Facility

- Algae Meal conversion to Acetone, Butanol, and Ethanol

USU Algae Processing and Products Facility

Pretreatment & ABE Production

100 Liter Reactors
At APP facility:
-Pretreatment
-ABE production
-Aqueous phase for bioplastic fermentor

Scale-Up of Bioplastics

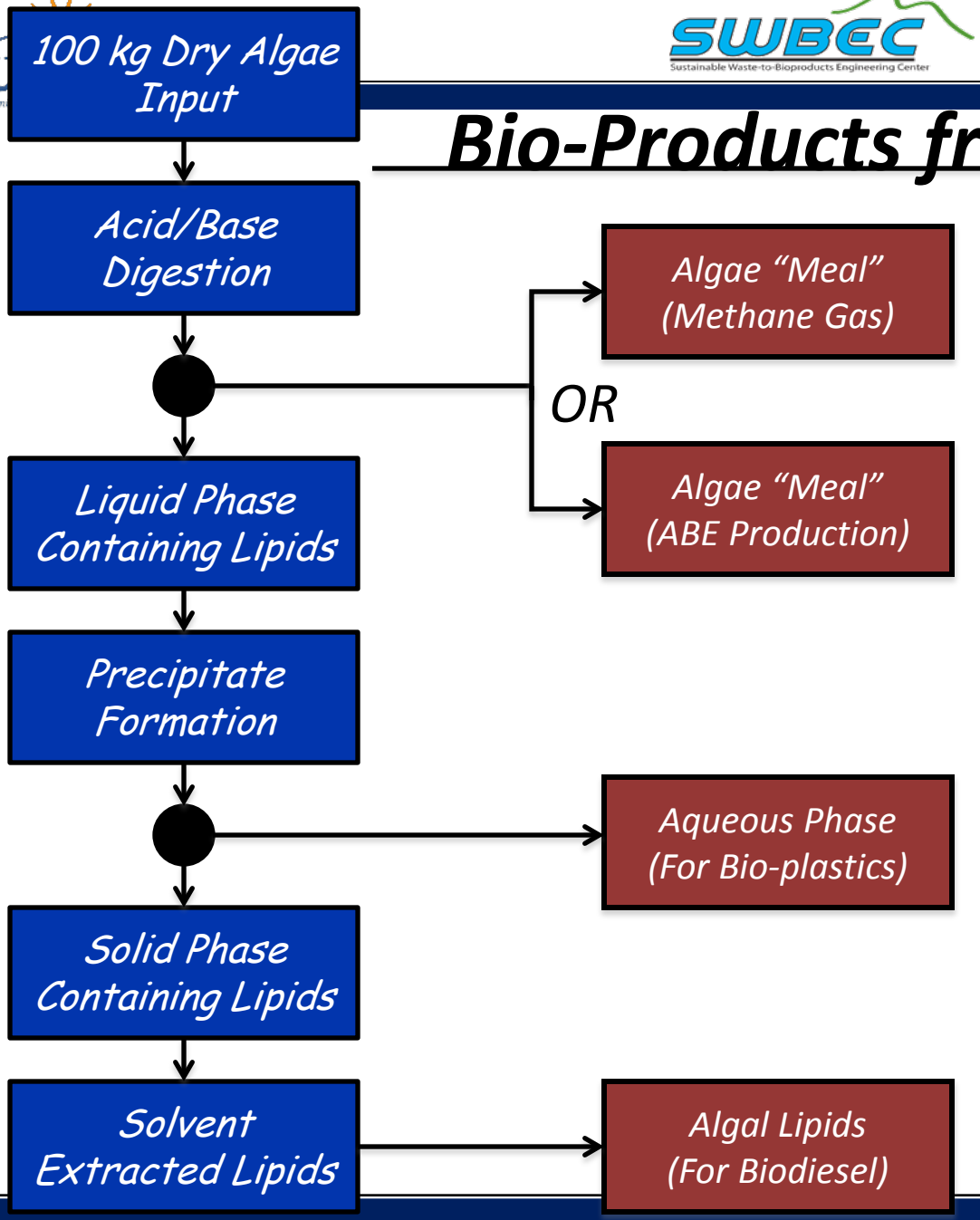
- *E. coli* strain development (48% PHB)
- Controls with glucose
- Operating parameters

10 L Fermentor

100 L

- Glycerol
- Algae aqueous phase
- Extractions
  - Chloroform
  - Sodium Hydroxide
  - Propylene Carbonate

Bio-Products from Algal Biomass



- *Methane generation via anaerobic digestion*
  - ***Methane energy potential - 1300 MJ***

- *Acetone, Butanol, Ethanol via Fermentation:*
- ***Total Solvents generated:***
  - ***Acetone 1.8 Liters***
  - ***Butanol 9.6 Liters***
  - ***Ethanol 0.67 Liters***

- *Polyhydroxybutyrate (PHB or bio-plastic) produced via genetically engineered E.coli*
- *Assume aqueous phase contains 0.5 g/L glycerol*
  - ***Total Bio-Plastic produced – 1.5 kg***

- *Assuming algae is 10% lipid by mass*
- *Based on complete extraction and conversion of lipids present in biomass*
  - ***Total Biodiesel yield – 11.34 Liters***

Estimated BioProduct Production from Logan City Wastewater Treatment Facility

Bioproduct	Production/Month
Methane Gas	250,000 kW*
Acetone	1,300 gallons
Butanol	6,900 gallons
Ethanol	480 gallons
Bioplastic	9,000 lbs
Biodiesel	8,200 gallons**

* Enough power to supply 280 homes

** Enough to fuel 20 solid waste trucks

Materials, Energy, Economic Analyses

Bioproduct	Market Value per Year[1]
Electricity (Methane)	$240,000
Acetone	$190,000
Butanol	$750,000
Ethanol	$23,000
Bio-Plastic	$540,000
BioDiesel	$400,000
Total Value	**$2,143,000**

- **[1]Logan, Utah Wastewater Treatment Plant**

Algae Scale-Up Processing 2012

- Acquired, instrumented, tested:
  - Algae pretreatment reactor
  - Fermentor for ABE production
  - Fermentor for bioplastic production
- Algae Processed:
  - 1,000 lbs (wet weight), mostly from RABR
  - 100 lbs (dry weight)
  - 1 lb (Bioplastic dry weight)
  - 2 liters of ABE

Algae Scale-Up Processing 2012

- Wet Lipid Extraction Procedure tested:
  - Pilot scale
- Focus on ABE and Bioplastic
- Extraction of PHB (bioplastic) from bacteria using propylene carbonate (cheaper, less volume, non-toxic, scalable)

SWBEC 2013

- Algae cultivation
  - Test new RABR design for higher productivity (more surface area per footprint area)
  - Test winter operation
  - Evaluate cyanobacteria growth for high-value products

SWBEC 2013

- Bioplastics
  - Production process in 125 L fermentor
  - Test PHB secretion strains
  - Expand testing of propylene carbonate for extraction and reuse
  - Techno-economic analysis
  - Scale-up PHB production using cheese whey as carbon source

SWBEC 2013

- Acetone, Butanol, Ethanol
  - Algae from new RABR (Biofilm)
  - Algae concentration in fermentor
  - Control of other organisms
  - Techno-economic analysis

SWBEC Summary

- Integrate wastewater remediation with bioproducts production
  - Wastewater as a resource
  - Environmental benefits
  - Local (not imported)
- Biofilm-based cultivation and harvesting
- Bioproducts industry world-wide benefits:
  - Sustainable bioenergy
  - Sustainable bioproducts
  - Environmental benefits
  - Local (not imported)