Wastewater Reclamation and Biofuel Production Using Algae

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Cal Poly Algae Technology Group

Recent Major Projects

- 2014 US DOE Algae Biomass Yield Project
- 2013 US DOE Water & Nutrient Recycling Project
- 2013 US DOE ATP^3 Testbed Site (Prime: ASU)
- 2011 CEC Algae Biofuels & Wastewater Reclamation
- Investigators from:
  - Engineering
  - Chemistry
  - Microbiology
  - Animal nutrition
  - Natural Resources
  - Food science

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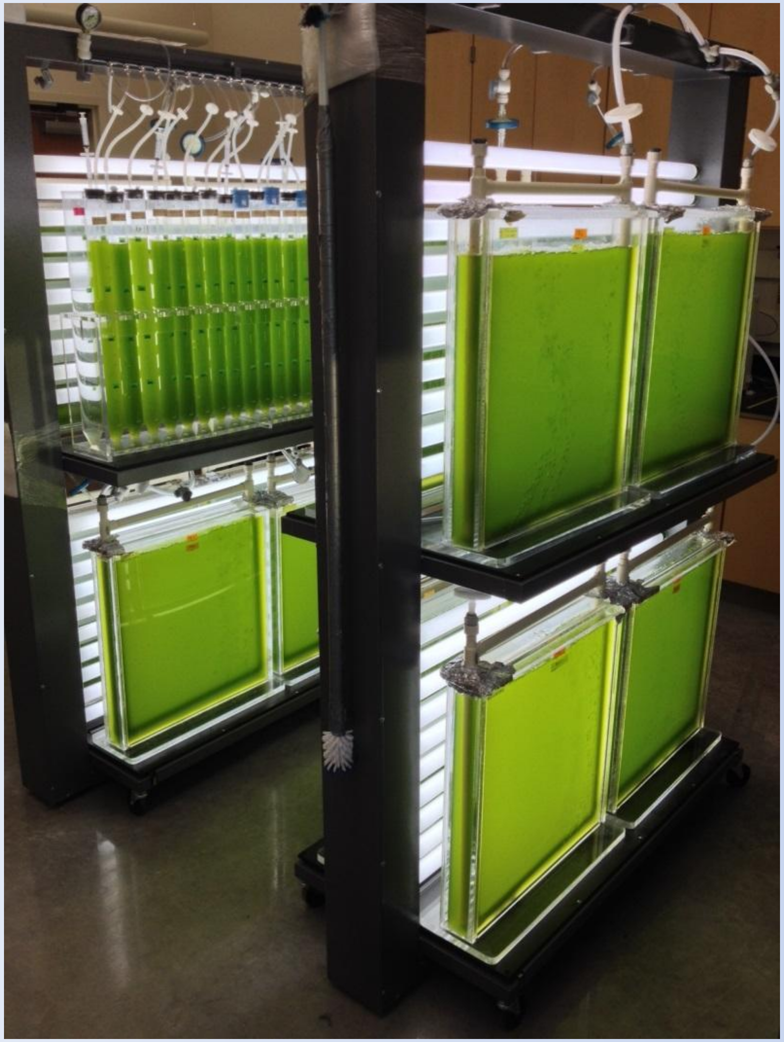
Cal Poly is an ATP^3 testbed site in ASU network.

ATP^3 has been a very fruitful project: Harmonization of production, lab standardization, and great collaboration.



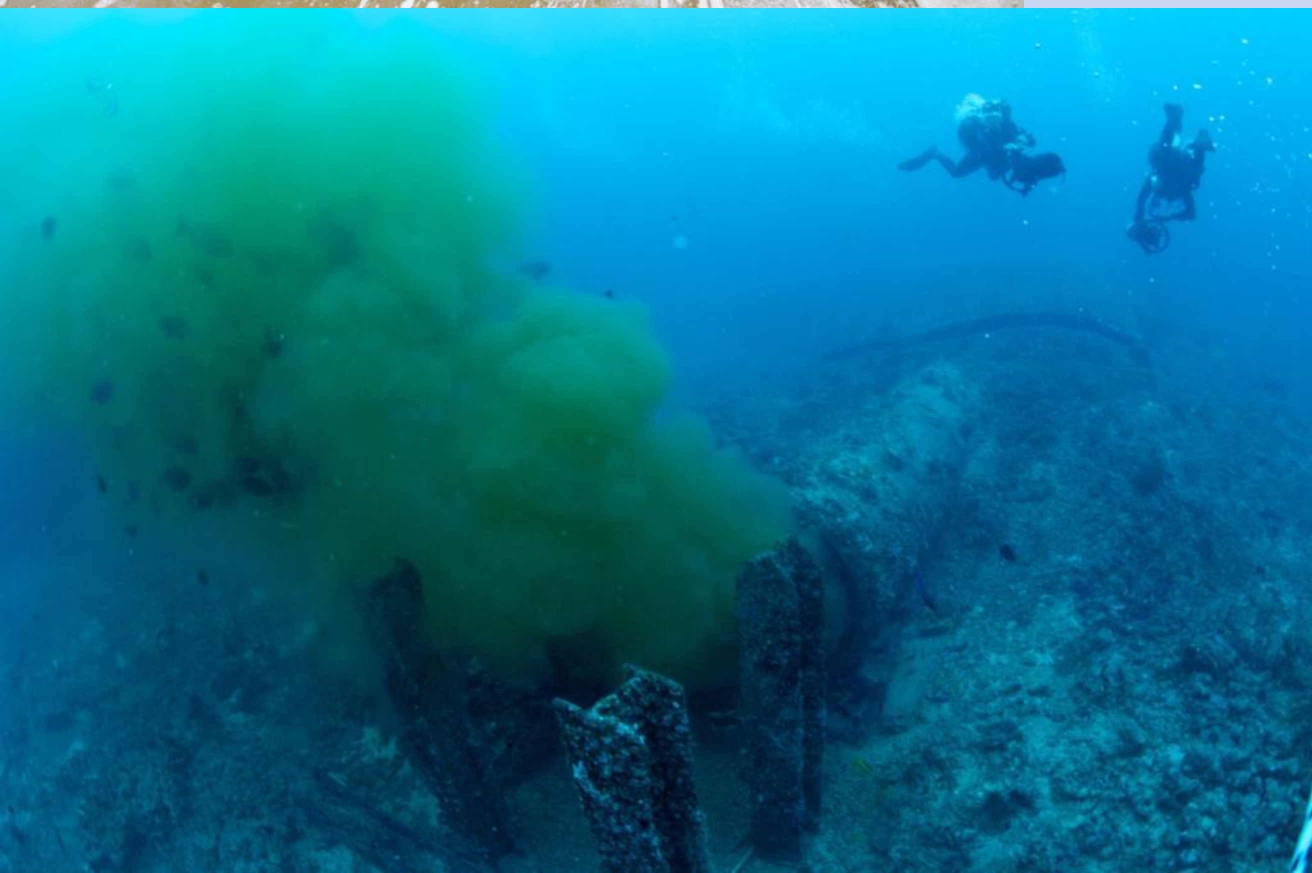
ATP3
Algae Testbed
Public-Private Partnership

Site of DOE Project with Cal Poly & MicroBio

Algae Wastewater Treatment Plant → Biofuel Plant



Wastewaters (WW) contain hazards but also resources…



Beyond protecting environmental water quality, the goals of wastewater treatment are to ...

Recycle water

Recover nutrients

Produce biofuels

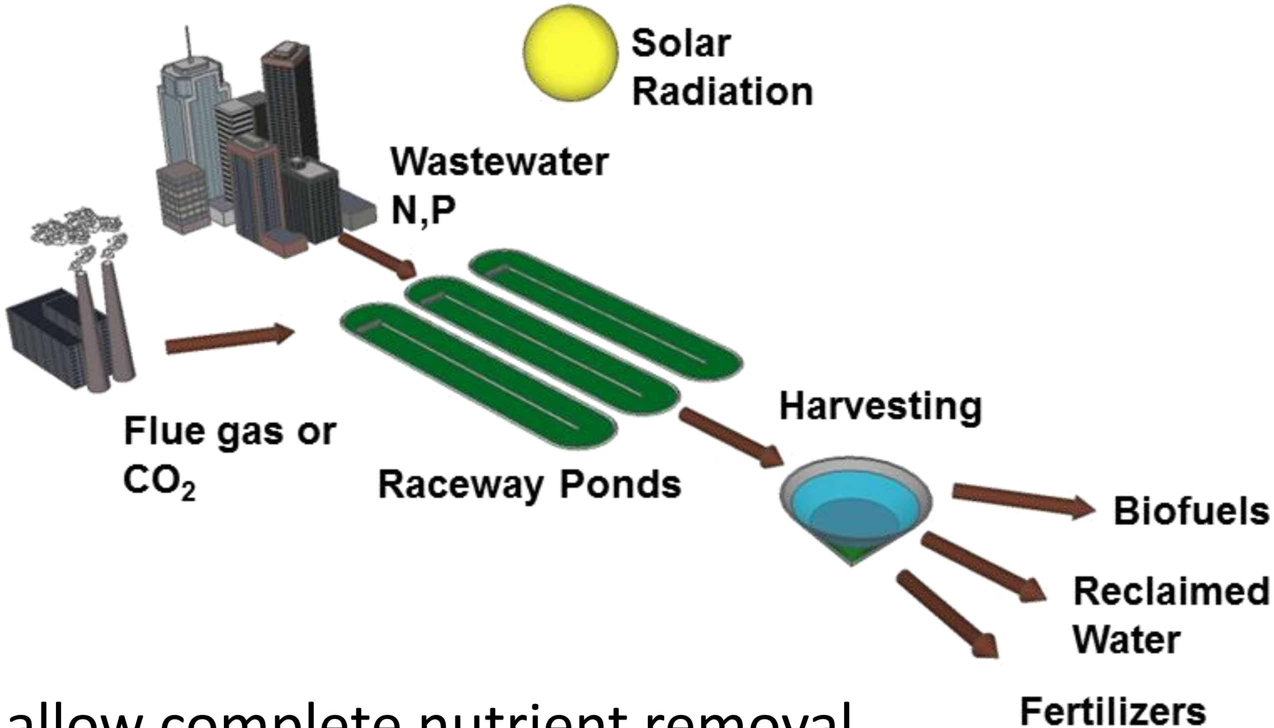
RNEW® Technology

Recycle

Nutrients

Energy

Water



- CO_2 addition to allow complete nutrient removal
- Harvesting by bioflocculation
- Low cost
- Low energy intensity vs. conventional treatment
- Biofuel via digestion or hydrothermal liquefaction

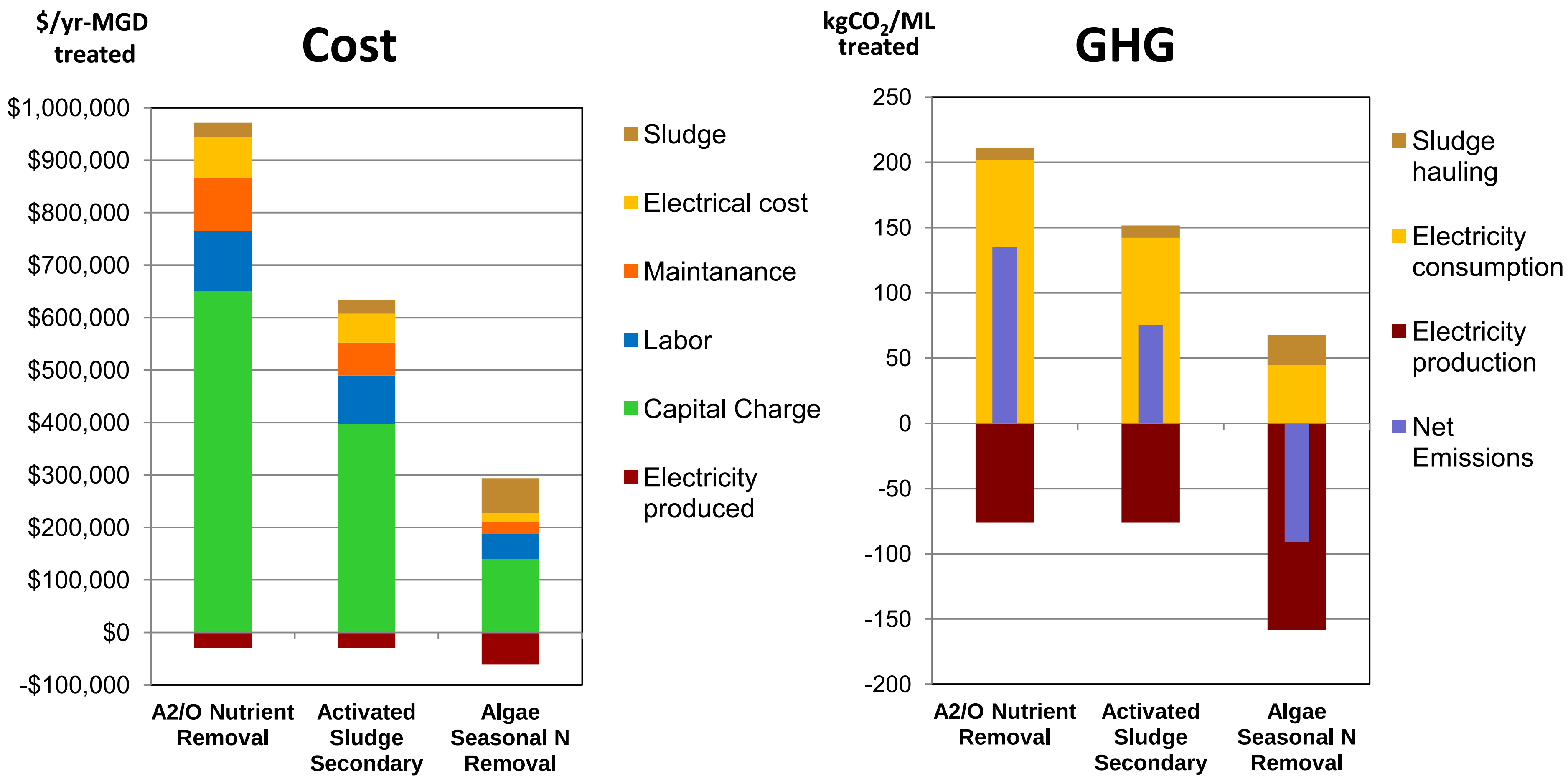
Full-scale raceway systems in California, Israel, S. Africa, New Zealand (but not designed for nutrient removal).



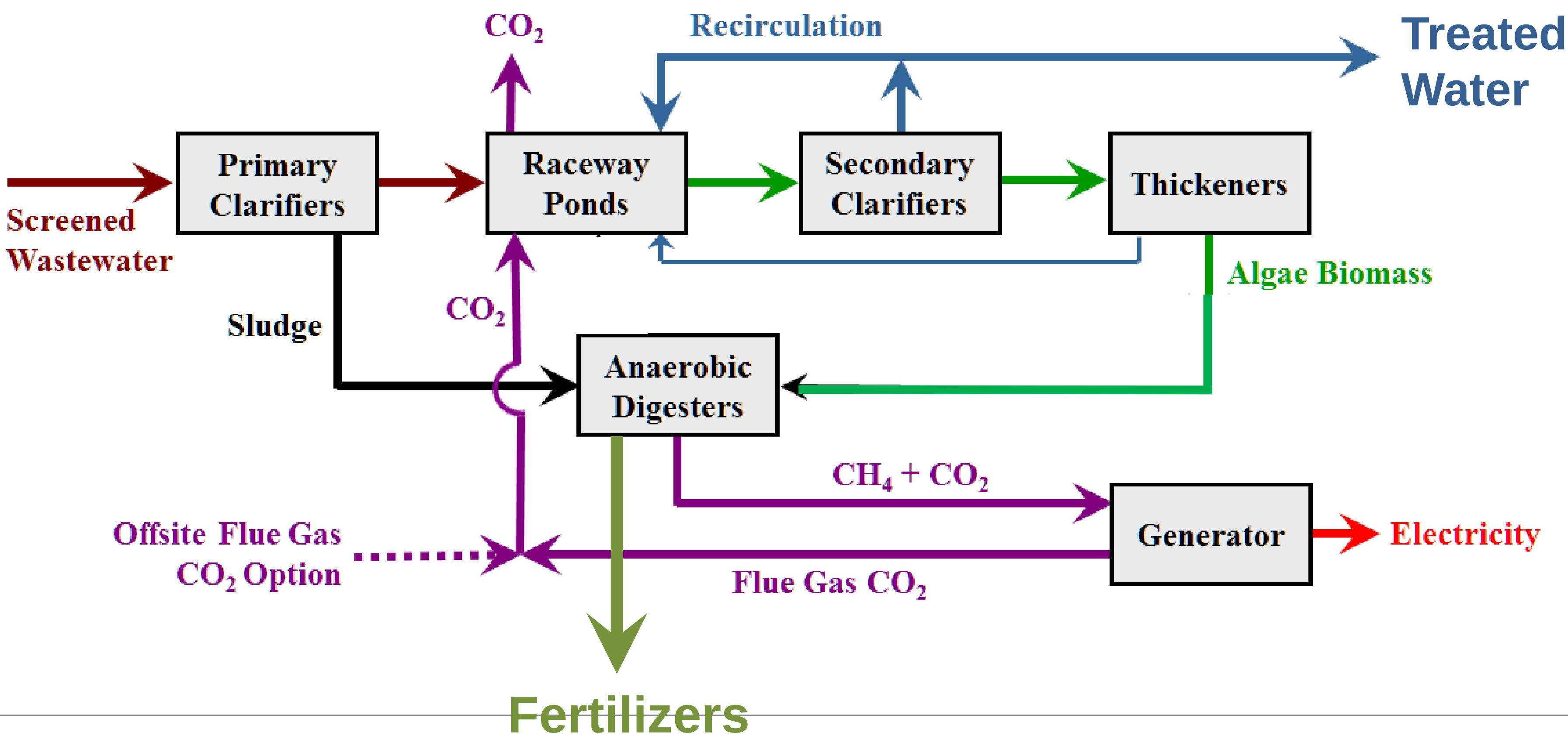

Typical Electro-Mechanical Treatment Plant

Algae wastewater treatment is low cost and energy efficient. Algae nutrient removal is seasonal.

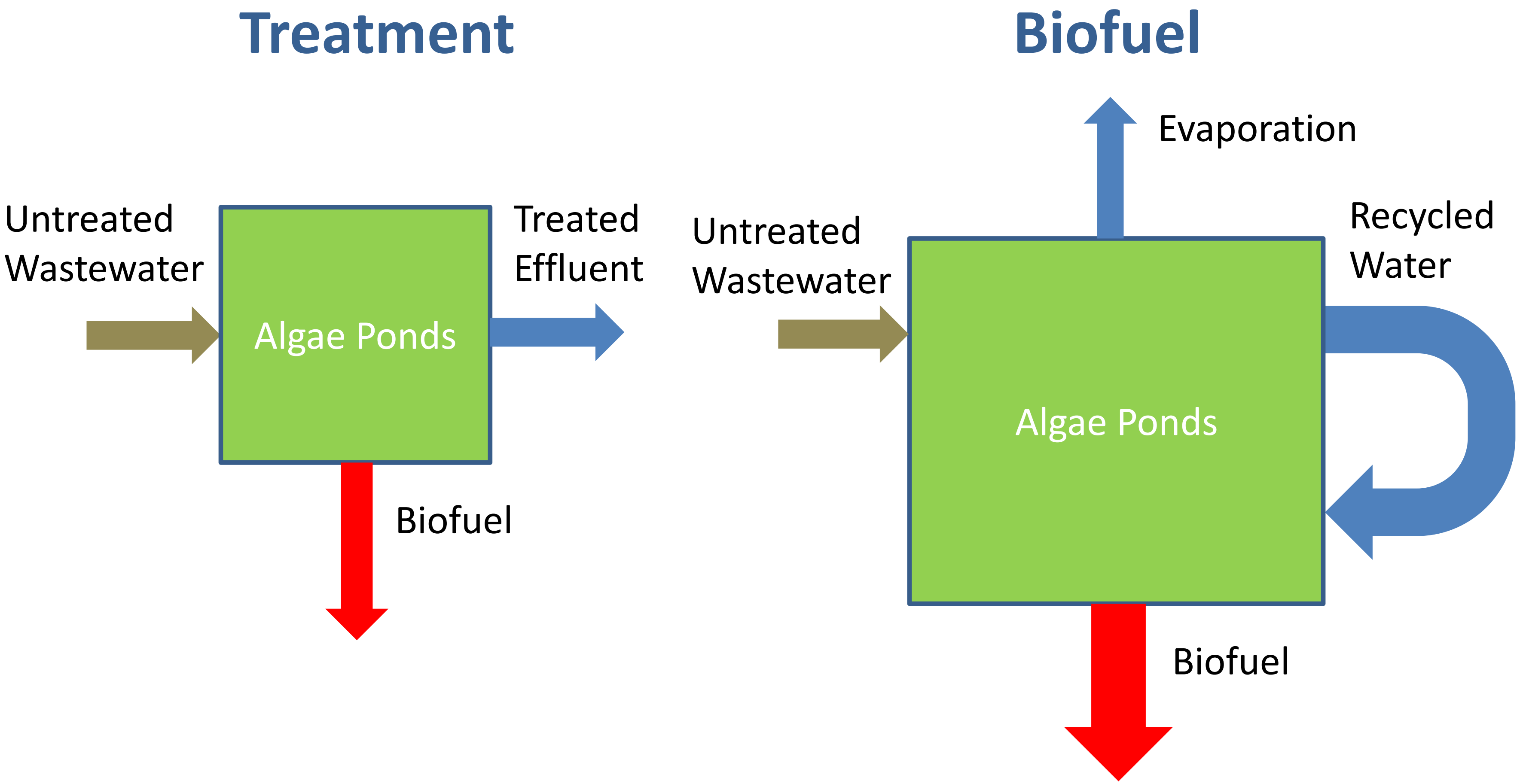
Save 50% total cost. Save 67% electricity (w/out biogas)



Algae wastewater treatment plant becomes a dedicated algae biofuel plant

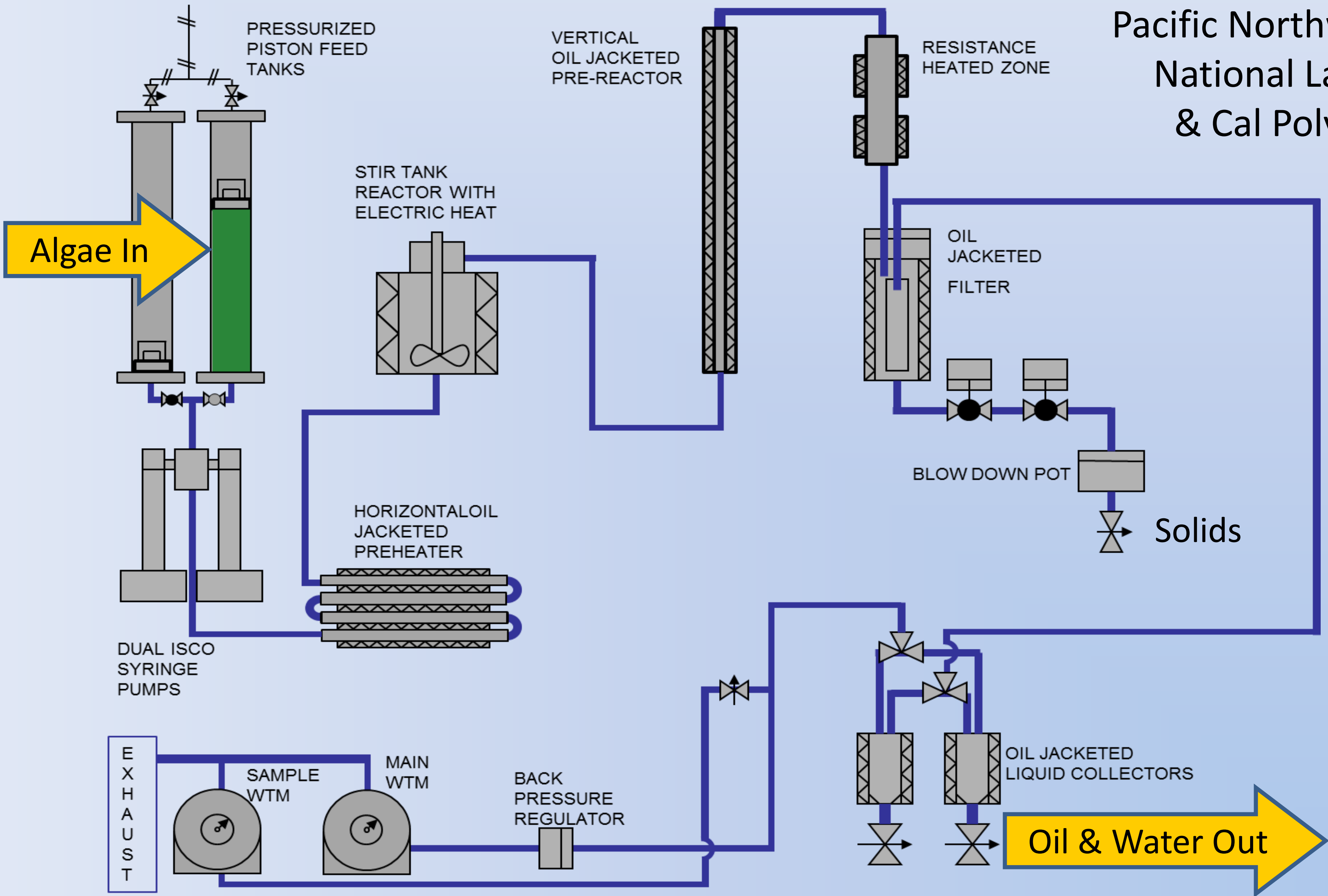


Wastewater recycling supports much larger cultivation area than just treatment.



"Pressure cooking" (hydrothermal liquefaction) converts algae to biocrude oil.

Pacific Northwest National Lab & Cal Poly



What does it take to reach 2500 gal/ac-yr?

Two main unknowns are to be determined in field studies:

Biofuel Intermediate Goal:

2500 gal/ac-yr = 6.4 mL/m^2-d = 6 g oil/m^2-d

HTL Conversion:

?? g oil / g biomass

Productivity:

?? g biomass / m^2-day

What kind of productivity?

With wastewater, we have gross, net, and autotrophic.

What does it take to reach 2500 gal/ac-yr?

Two main unknowns are to be determined in field studies.

Biofuel Intermediate Goal:

2500 gal/ac-yr = 6.4 mL/m^2-d = 6 g oil/m^2-d

HTL Conversion:

0.35 g oil / g biomass *(preliminary result)*

Productivity Need:

17 g biomass / m^2-day

If harvesting - dewatering efficiency is 85%:

20 g biomass / m^2-day needed

Add CO_2 to balance C:N:P ratio and achieve completed nutrient assimilation.

CO_2 Enhanced

600 mg/L Algae

<1 mg/L NH_4^+-N

<0.3 mg/L PO_4^{3-}-P

Air Sparged

130 mg/L Algae

25 mg/L NH_4^+-N

3 mg/L PO_4^{3-}-P

Lundquist et al., Cal Poly

Algae Field Station for wastewater treatment & biofuels at San Luis Obispo, California

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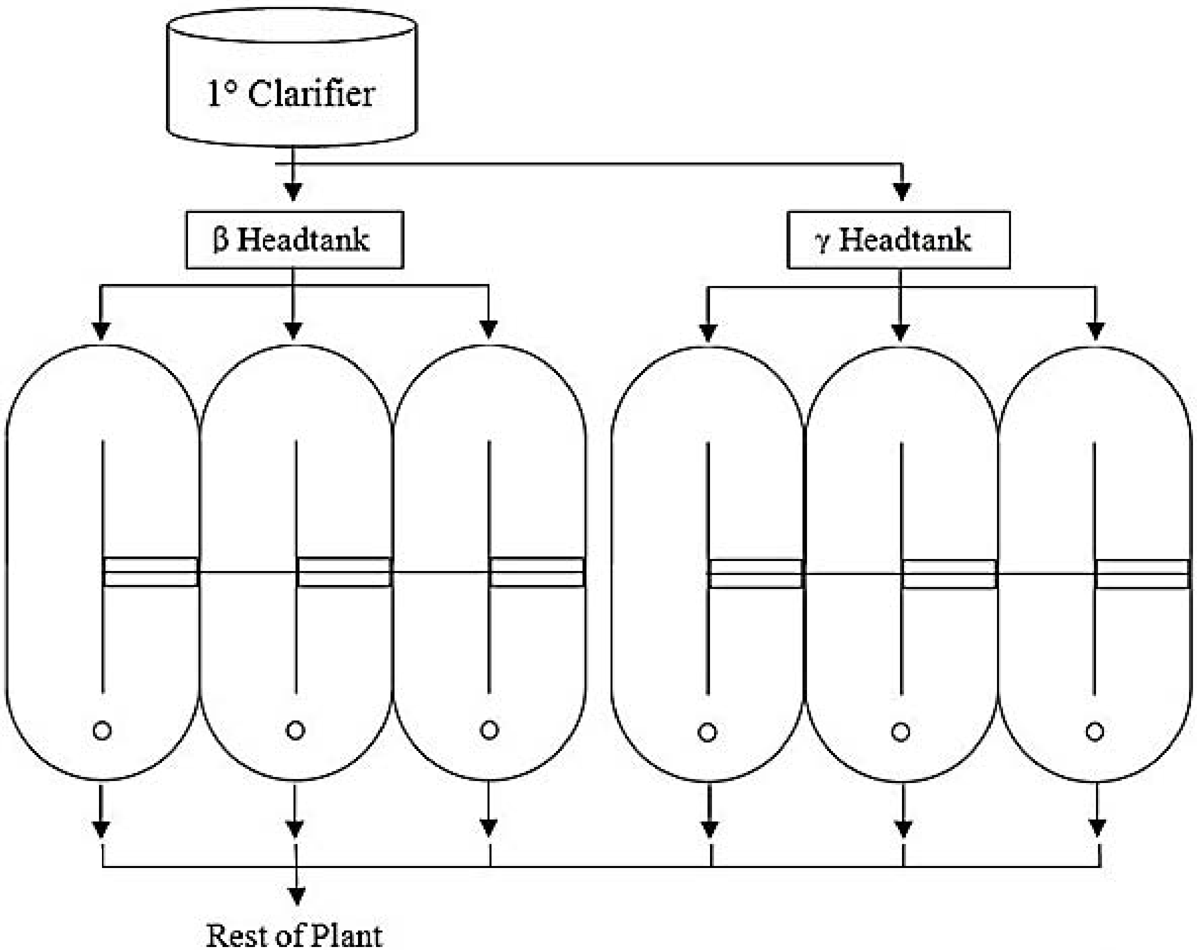
2-day vs. 3-day hydraulic residence times tested.

Compared productivity & treatment.

2-day



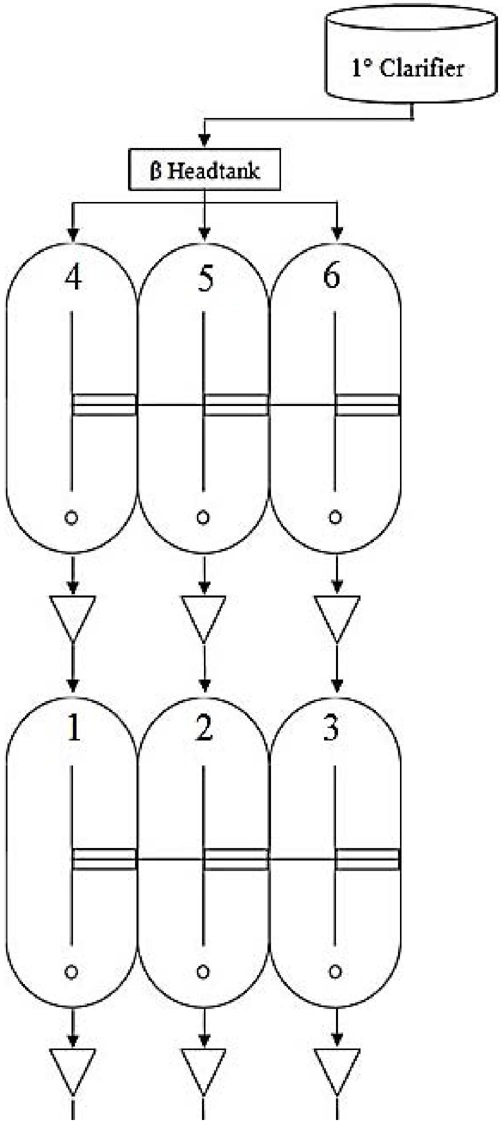
3-day

Ponds-in-series test for treatment & water reuse

For biofuels, water reuse builds-up inhibitory compounds.

3-day

3- or 4-day



Objectives:

1. Total N ≤ 10 mg/L throughout winter.
2. Compare productivity.

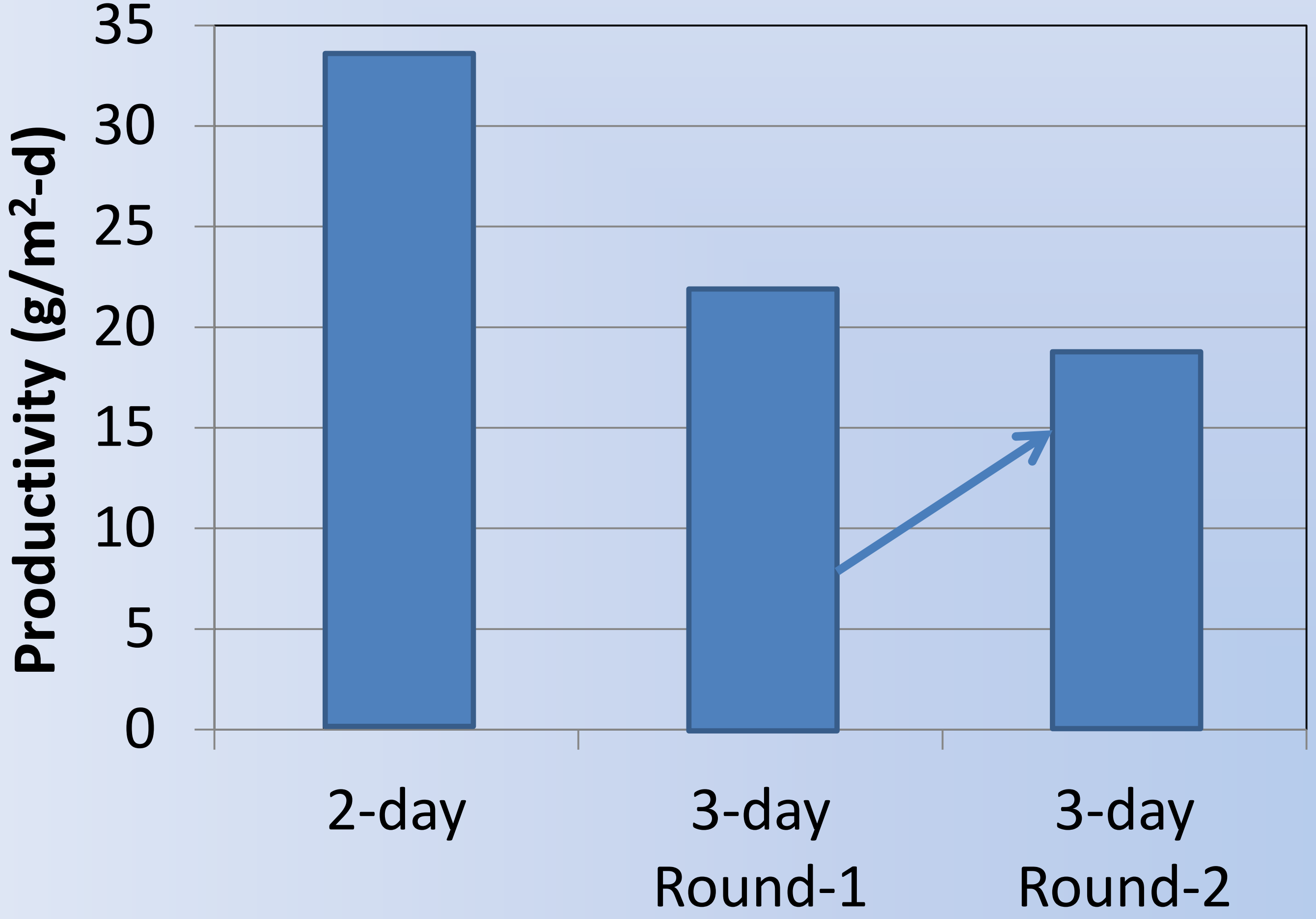
CO_2 Addition:

ON at pH 8.6

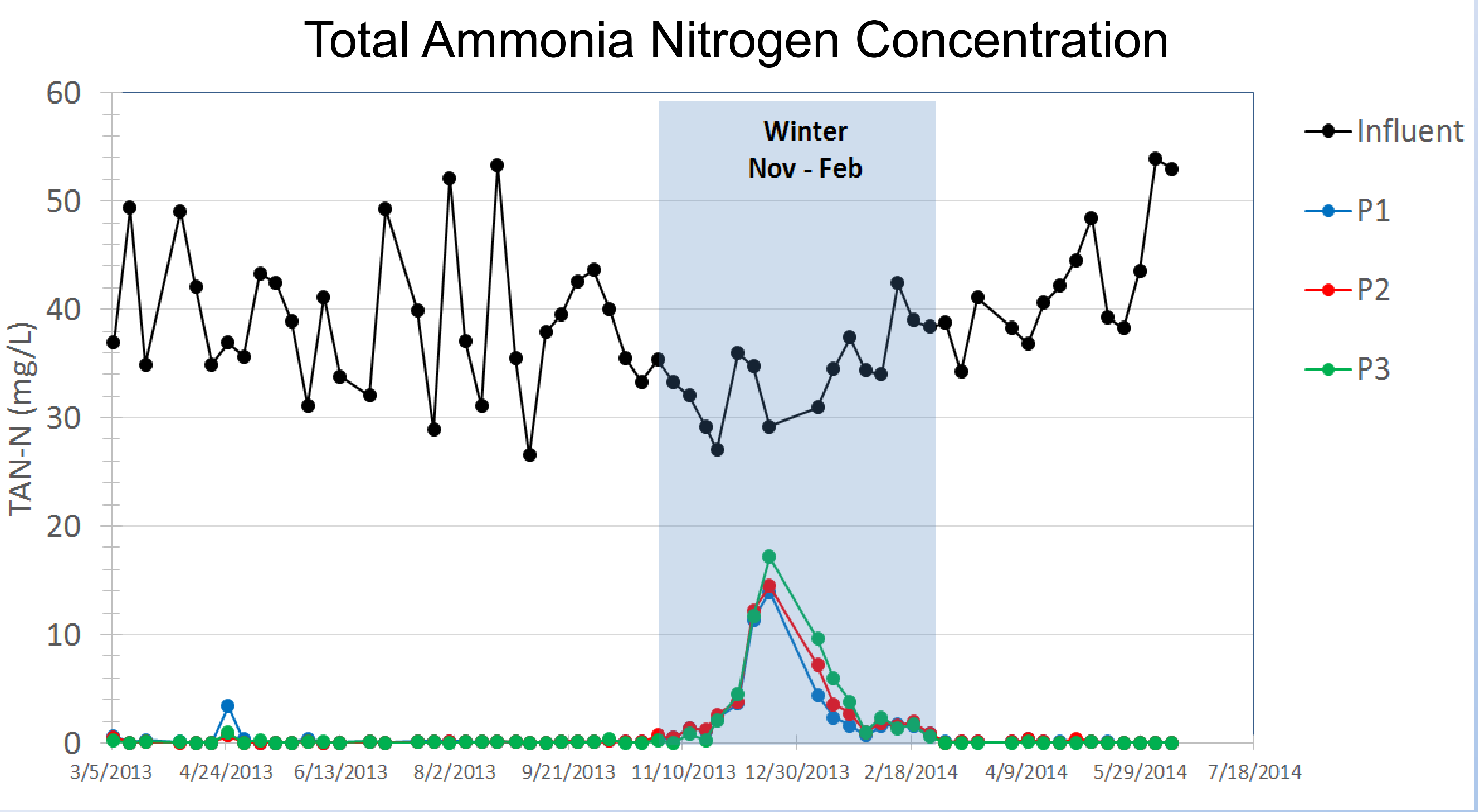
OFF at pH 8.5

Great productivity with wastewater raceways!

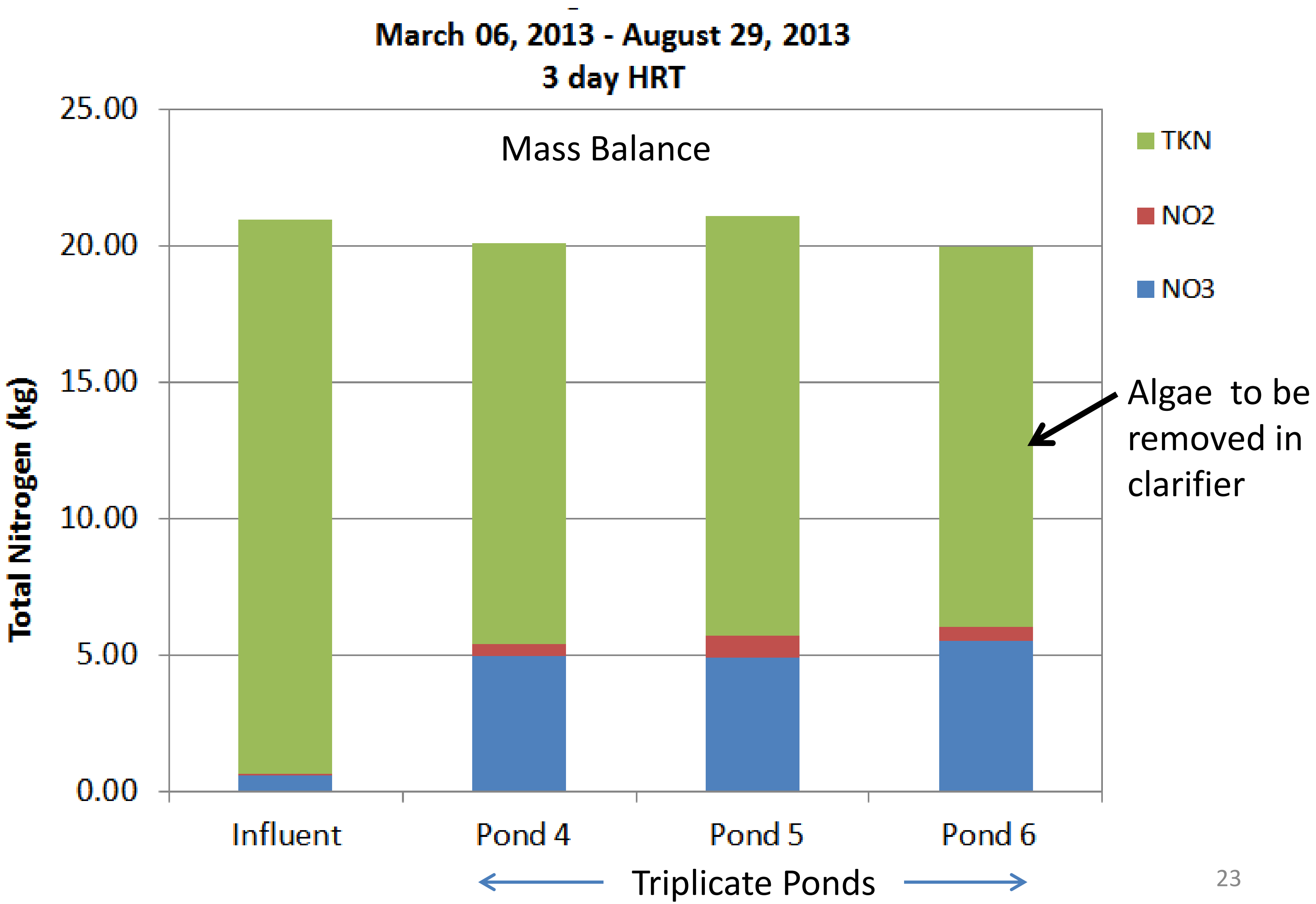
But what is "algae productivity" in media with organic matter? What is the autotrophic portion? Why care?



Good ammonia nitrogen removal except mid-"winter" when mechanical aeration needed.

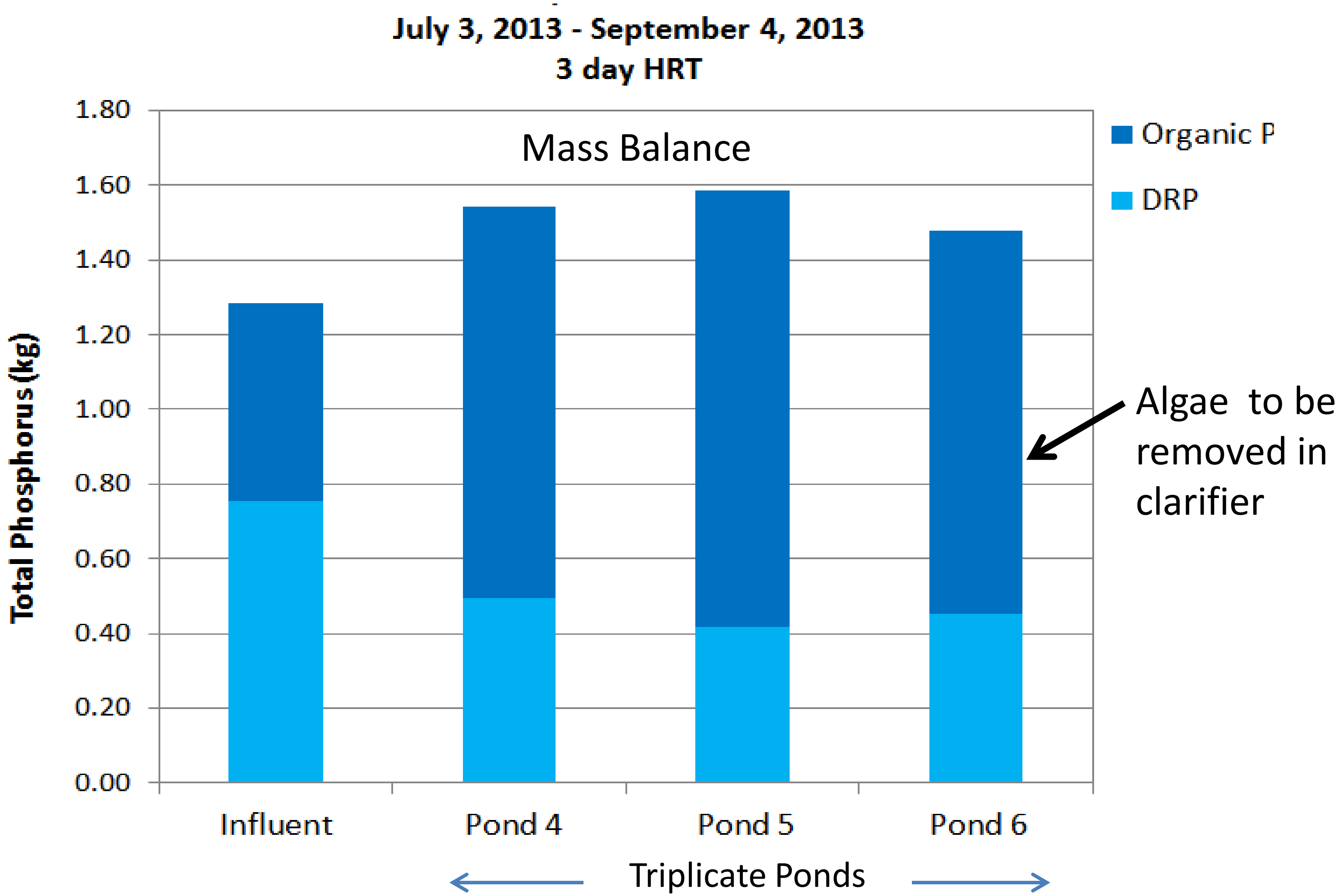


Nitrification occurs, but not ammonia volatilization at pH 8.5 in 33-m^2 raceways.



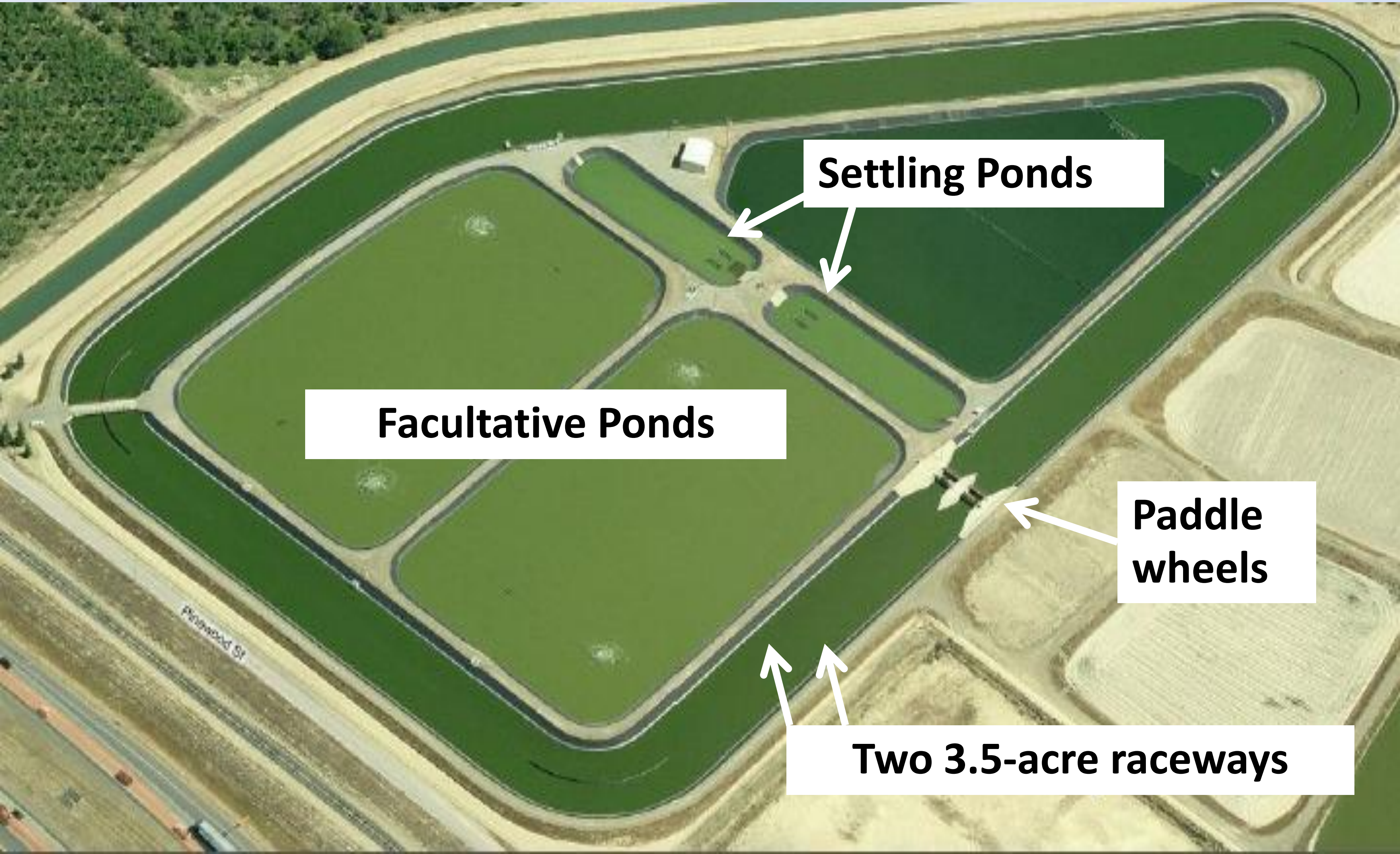
Phosphorus removal would need 3-4 rounds of growth in places needing <0.5 mg/L P.

R&D on "luxury uptake" of excess P needed.



Site of DOE Project with Cal Poly & MicroBio

Algae Wastewater Treatment Plant → Biofuel Plant



At full-scale, algae are coagulated, settled, and solar dried.

~100,000 gallons of 3% solids algae in decanted settling basin

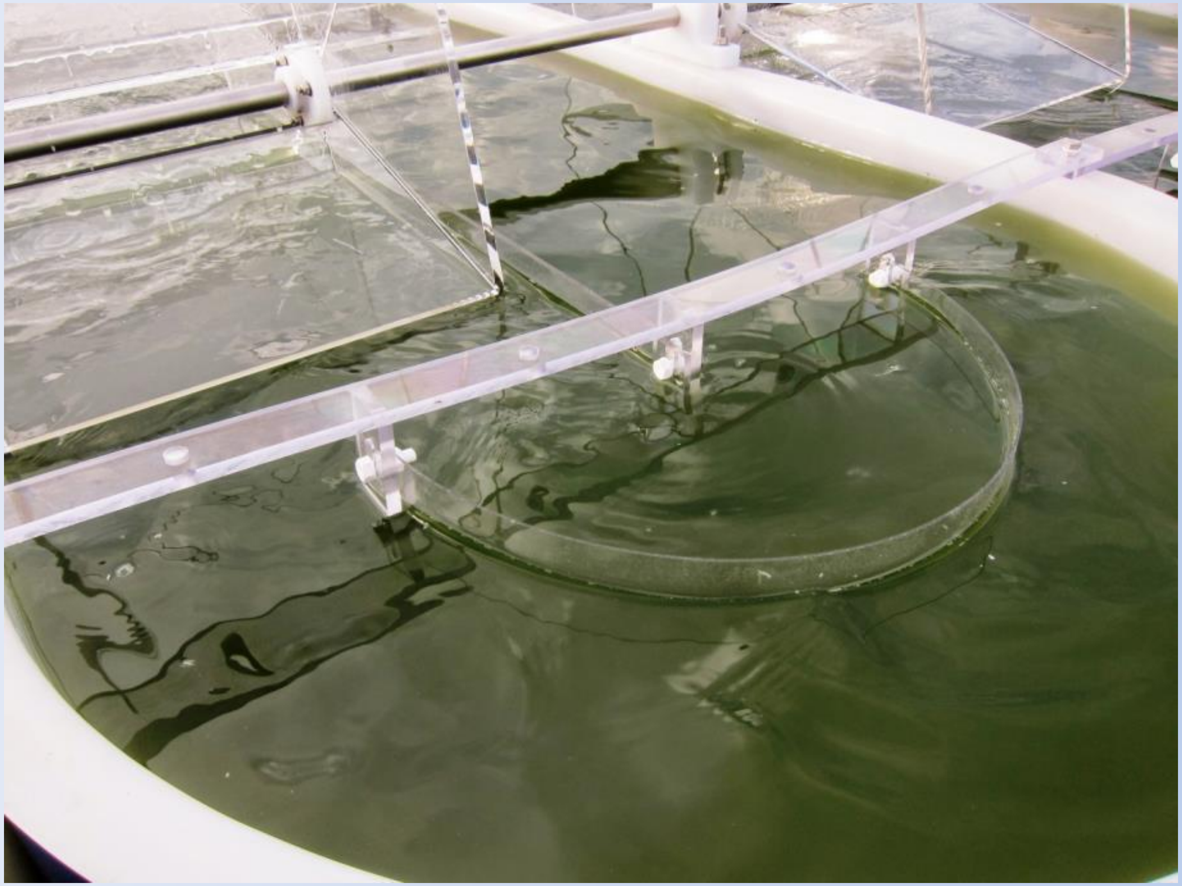
Solar dried algae

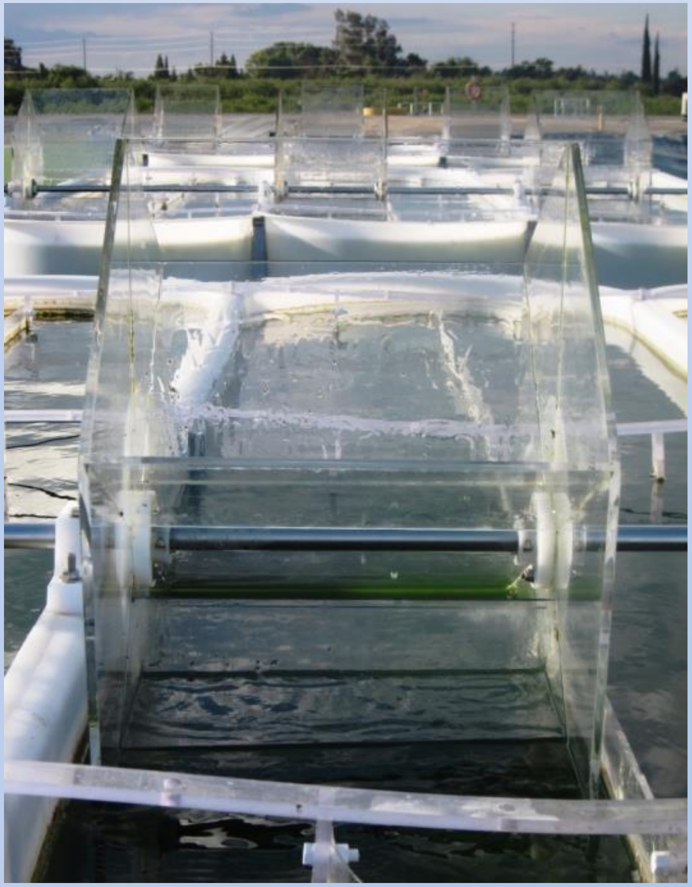
Concrete drying pad

We run three conditions in triplicate.
Goal: maximize productivity and treatment.

Edge effects in pilot units throw off scale-up projections.

- Edge effects from shading are minimized with transparent paddles and dividers.





Remote control and data logging capabilities

Feed rates, CO_2 dosing, paddle speeds, etc. can be changed on timer basis or remotely.

Primary Clarifier
2-hour residence time

Pilot-Scale Raceways
2-5 day HRT

Algae Settlers
(2-3 hours)

Algae

Treated Wastewater

Algae Drying Beds & Screens

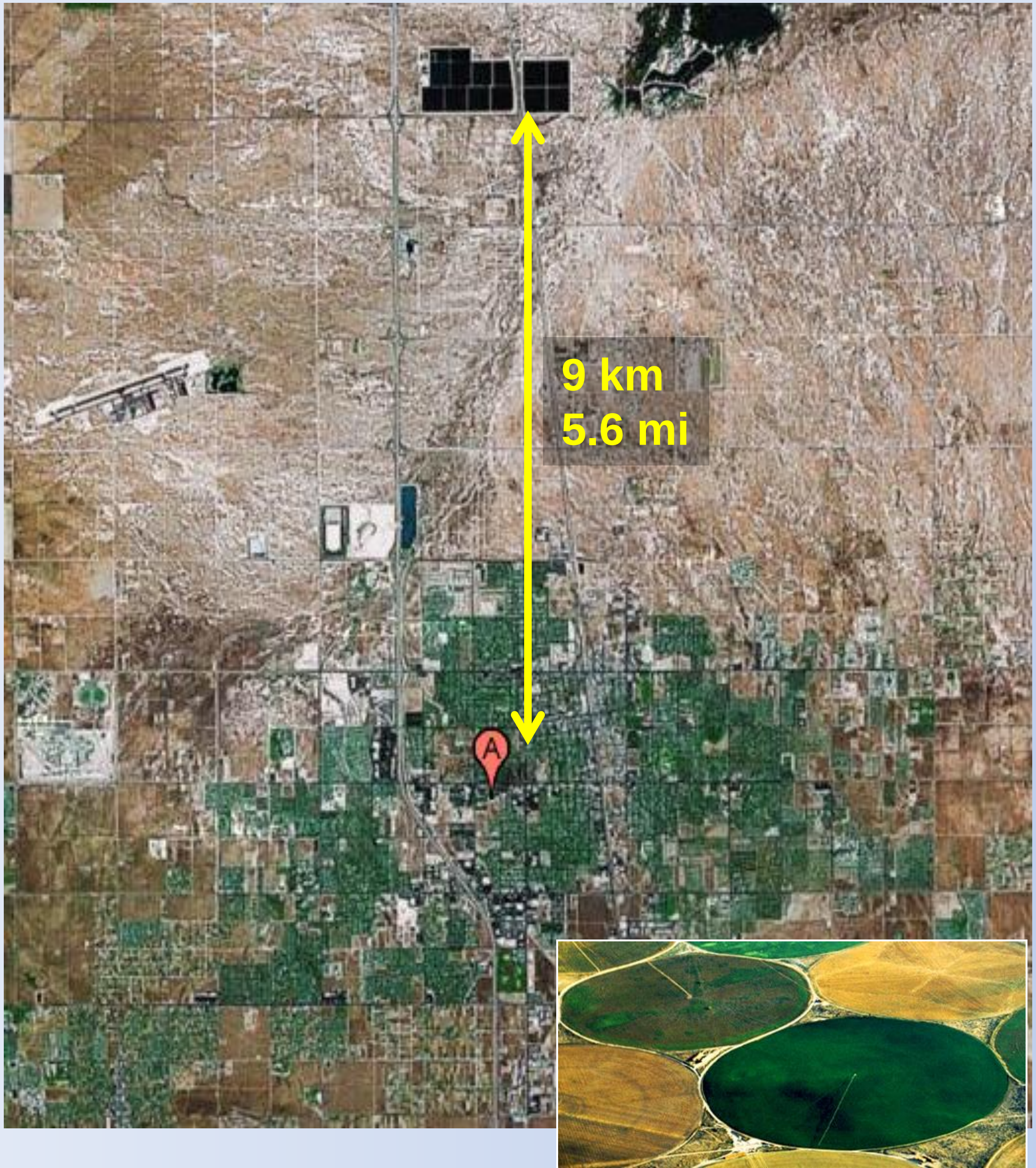
Algae Thickener

Supernatant Tank

Are large raceway facilities practical?

A 1,000-acre algae biofuel facility takes in 12 million gallons per day of wastewater (120,000 population)

Wastewater pipelines out of town are common.



Lancaster, California
157,000 population

Effluent used for alfalfa irrigation.

Water and nutrients are recycled at low running cost, but pipeline investment needed.

Converted to activated sludge due to N limit. Now N fertilizer is purchased.

Stockton, California
292,000 population

Land was reserved early. Now city has grown to the edge of the ponds.

Used by Audubon Society for bird watching.

City owns real estate under the ponds that is now valuable.

Napa, California
77,000 population

Treated pond effluent is discharged to a river during winter and used to irrigate pasture and soon grape vineyard during summer.

Modesto, California
485,000 population

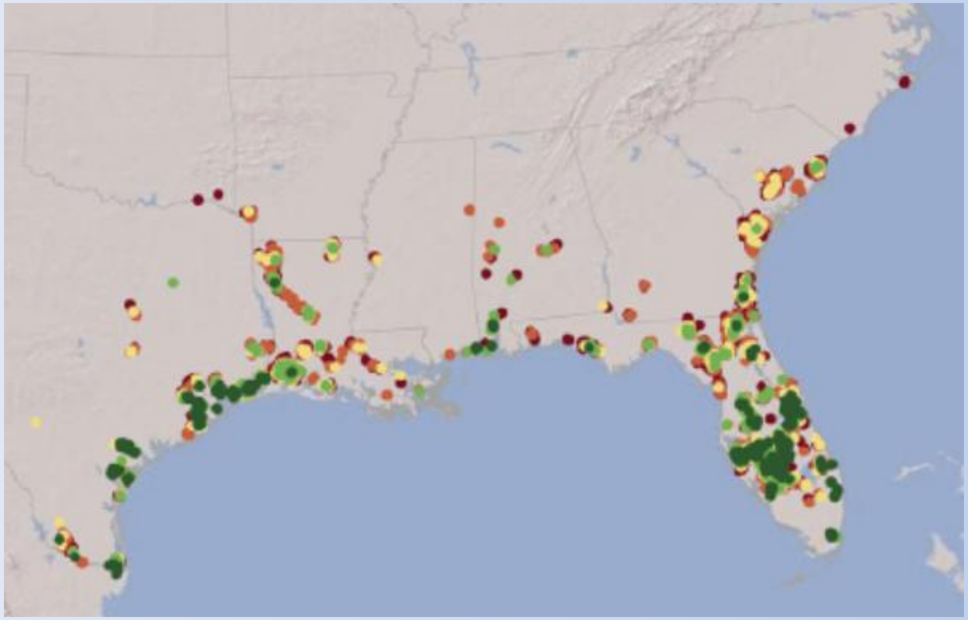
During winter, treated effluent is partly stored in reservoirs and partly discharged to a river.

During summer, City-owned cattle pasture is irrigated.

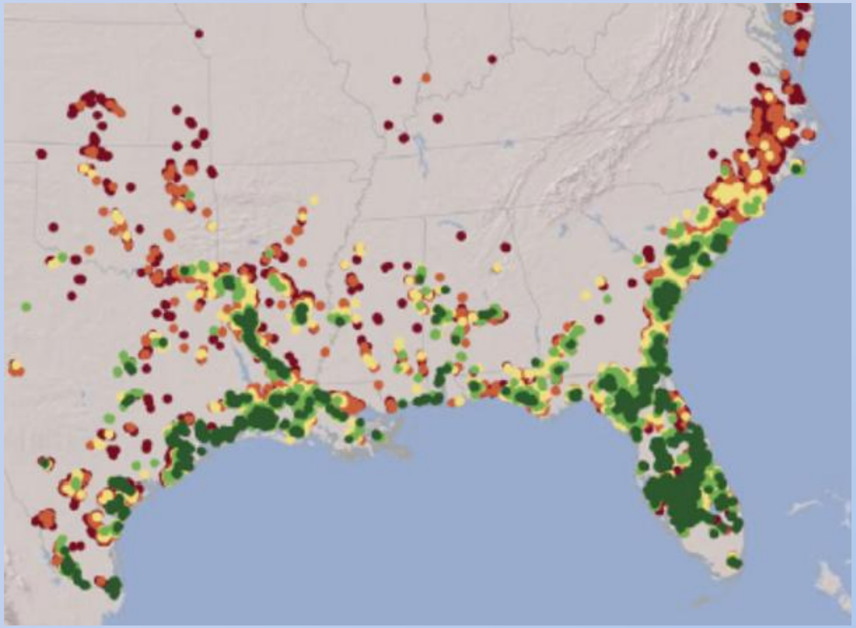
In US, 5 billion gallons per year (BGY) of algae biofuel is feasible with wastewater use, but 21 BGY may outstrip supply of municipal and animal wastewaters. [Preliminary, 2014 Venteris et al.]

21 BGY is US aviation kerosene use. [

5 BGY in 2900 farms



21 BGY in 14,000 farms



2014 Venteris, Skaggs, Wigmosta, Coleman

Algae + wastewater + biofuel: Why do it?

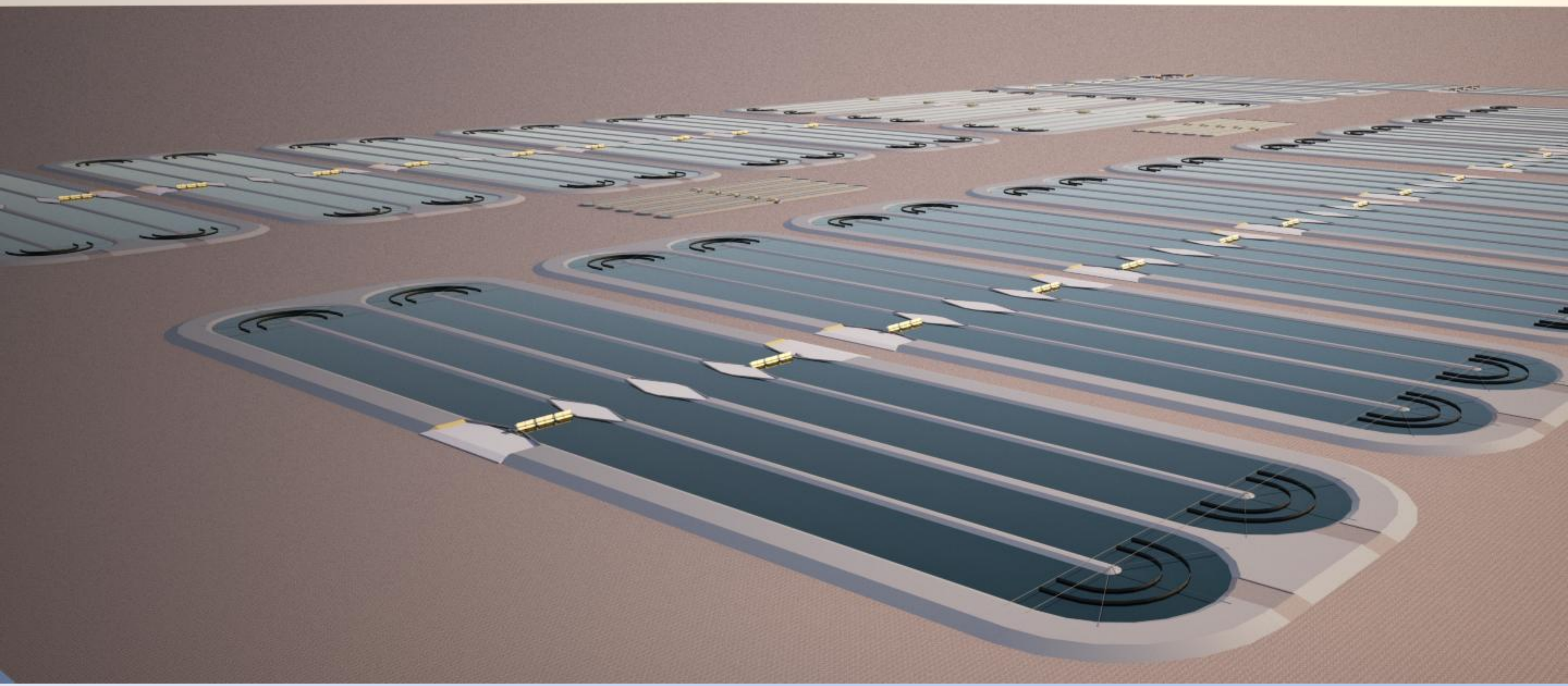
WW-supported biofuel is small compared to need but…

- 5-20 billion gallons is still a lot and we need to make use of every feedstock.
- WWT is needed regardless.
- WWT is expensive, but algae cuts the cost.
- Algae WWT saves electricity.
- Algae WWT captures nutrients for reuse.
  - But with increased hnadling and trucking costs
- Treat WW: Get your feedstock for free.
- High fuel:co-product ratio with reclaimed water.
- Build algae production expertise and capacity.

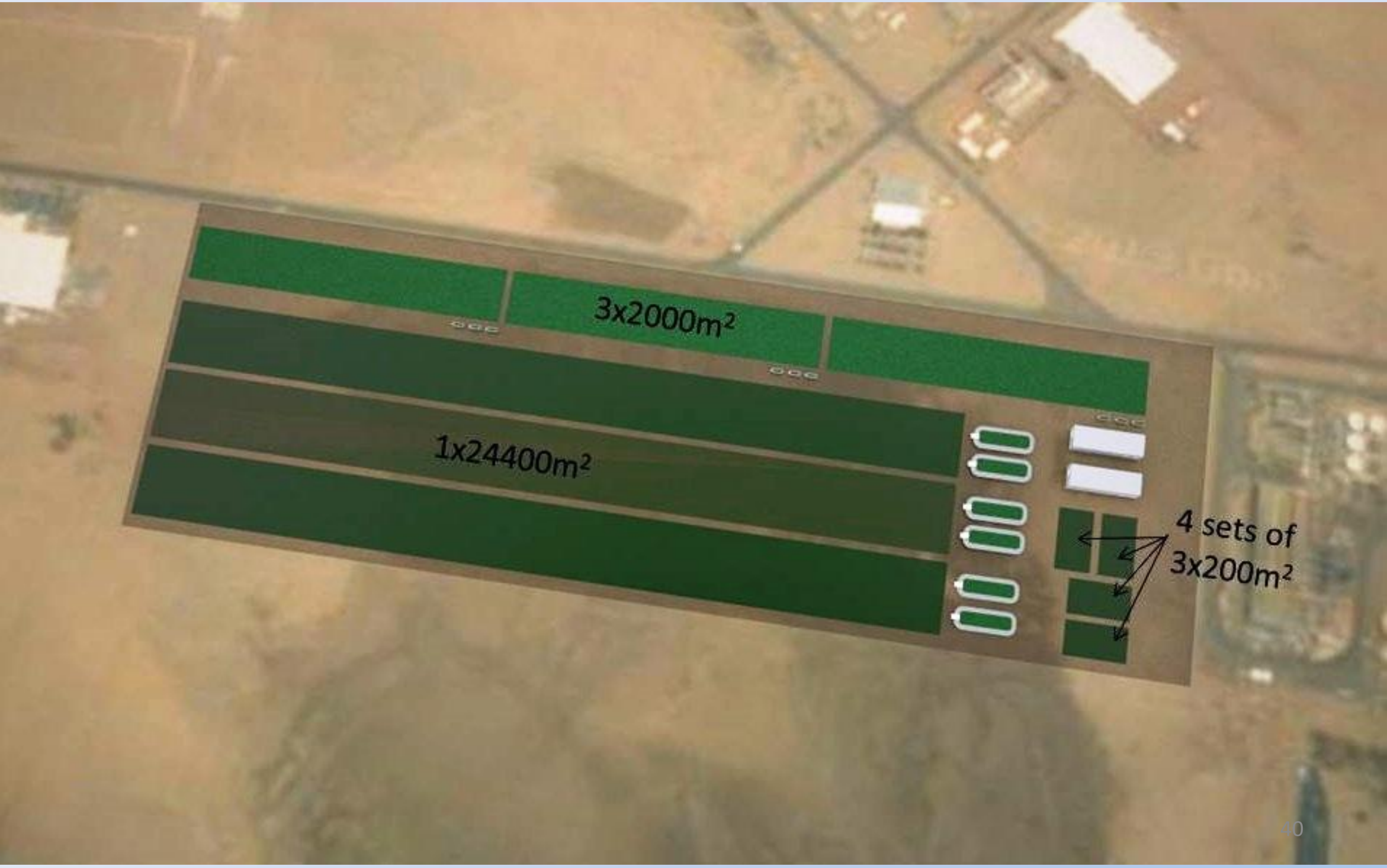
Global Interest: Current proposals for algae WWT, biofuel, and aquaculture projects

1,500 acres (600 ha) site-specific algae production facility rendering.

Biofuel project under construction currently.



Aquaculture pilot plant with flue gas CO_2



High value product proposal

Conclusion

Algae

Wastewater

Acknowledgments

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Other Partners:

- **Arizona State University – ATP^3 Project**
- **Pacific Northwest National Lab (M. Huesemann, D. Elliott)**
- **Sandia National Laboratory (Lane)**
- **LiveFuels and Phitech**
- **Ruth Spierling, Ian Woertz, Neal Adler, John Benemann, Braden Crowe, Shelley Blackwell, and many more. Thank you!**

Thank you for your attention

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