DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

Algal Biodiesel via Innovative Harvesting and Aquaculture Systems

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Algal Feedstocks

Jeffrey S. Kanel, Ph.D.
Renewable Algal Energy, LLC (RAE)

Goal Statement

- **Goal 1:** Demonstrate a prototype algal harvesting process at a sufficient scale (>300,000 U.S. gallons [1,135,632 liters] of algae culture processed per day) to facilitate commercial scale-up.
- **Goal 2:** Show that the energy intensity of the harvesting process does not exceed 10% of the energy content of the algal biomass being processed.
- **Algal Feedstock Logistic Area**: Harvest: Dewatering & Concentrating
- **BETO MYPP Goal Addressed:** "Demonstrate technologies to produce sustainable algal biofuel intermediate feedstocks that perform reliably in conversion processes to yield renewable diesel …"
- **U.S. Relevance:** Demonstrated harvesting technology brings algal oil closer to commercialization as a feedstock for renewable diesel.

Quad Chart Overview

Timeline

- Project start date: 10/1/10
- Project end date: 9/30/14
- Percent complete: 100%

Budget

	Total Costs FY 10 –FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding FY 15
DOE Funded	$1,716,953	$524,944	$750,000	$0
Project Cost Share (Comp.)*				

Barriers

- Barriers addressed
  - AFt-D. Sustainable Harvesting
  - AFt-H. Overall Integration and Scale-Up

Partners

- Partners
  - None
- Other interactions/ collaborations
  - **Neste Oil** – algal oil analysis
  - **ABB, Inc.** – process control, automation, and equipment

1 - Project Overview

- History:
  - RAE Successfully completed DOE Phase I and II Small Business Innovation Research (SBIR) Grants to collect harvester scale-up data
- Context:
  - RAE Scientists and Engineers have commercial experience with algae since 1993
- Objectives:
  - Demonstrate scalable algal harvesting technology that can be deployed at commodity scale

2 – Approach (Technical)

- Apply scalable technology that is commonly deployed in mining and minerals to algae harvesting.
- Confirm that the technology can be scaled from 10 to 208 gallons per minute (gal/min) [38 to 787 liters/min] by utilizing data collected during Phase I & II SBIR Grants to design and engineer the 208 gal/min harvester.
- Prove the harvester can be constructed and operated at 208 gal/min at desired rates to minimize technology scale-up risks.
- Implement full automatic process control so that the automation technology is directly transferable to a 2,000 gal/min [7,571 liters/min] commodity harvester.
- Demonstrate technology performs reliably with automatic process control.

2 – Approach (Management)

- Validate that the technology produces algal oil suitable for use in transportation fuel.
- Demonstrate the value of the algal protein and other co-products as they impact the overall project value.
- Validate that the technology facilitates production of algal oil at a cost that is economically viable in the commodity marketplace.
- Confirm that technical support is available around the world so that the technology can be deployed globally.
- Deploy project management tools typical of industrial projects to achieve the desired project goals.

3 – Technical Accomplishments/ Progress/Results

- **Goal 1:** Demonstrated a prototype algal harvesting process at a sufficient scale (>300,000 U.S. gallons of algae culture processed per day = 208 gal/min [787 liters/min]) to facilitate commercial scale-up.
  - *Designed and engineered the harvester (208 gal/min scale)*
  - *Constructed and tested the harvester*
  - *Demonstrated robust operation with automatic process control*
  - *Operated harvester continuously for more than 24 hours with automatic process control at a rate of 208 gal/min*
- **Goal 2:** Demonstrated that the energy intensity of the harvesting process does not exceed 10% of the energy content of the algal biomass being processed.
  - *Process control offered continuous measurement of energy usage*
  - *Algal biomass recovery from harvesting was quantified*

3 – Technical Accomplishments/ Progress/Results (cont'd)

Figure 1. Continuous harvester capable of processing more than 300,000 U.S. gallons/day of algae culture (=208 gal/min [787 liter/min]).

3 – Technical Accomplishments/ Progress/Results (cont'd)

Figure 2. Night operation of harvester.

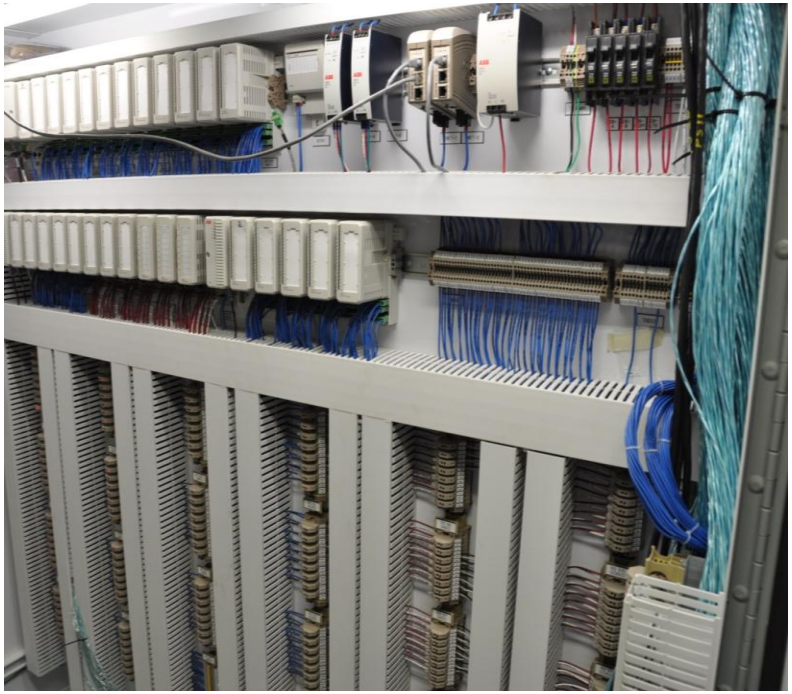
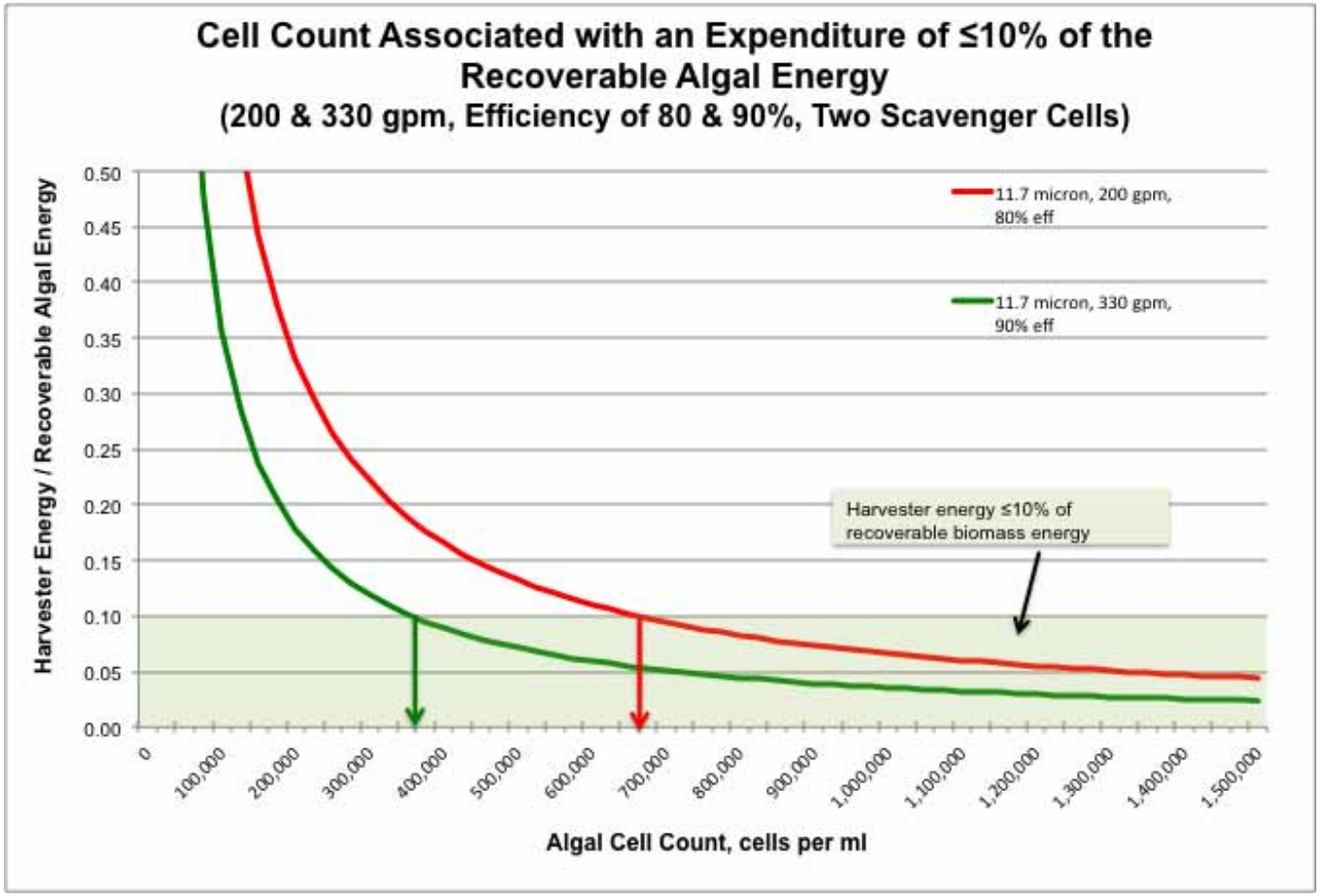


Figure 3. IO panel for the process instrumentation and control.

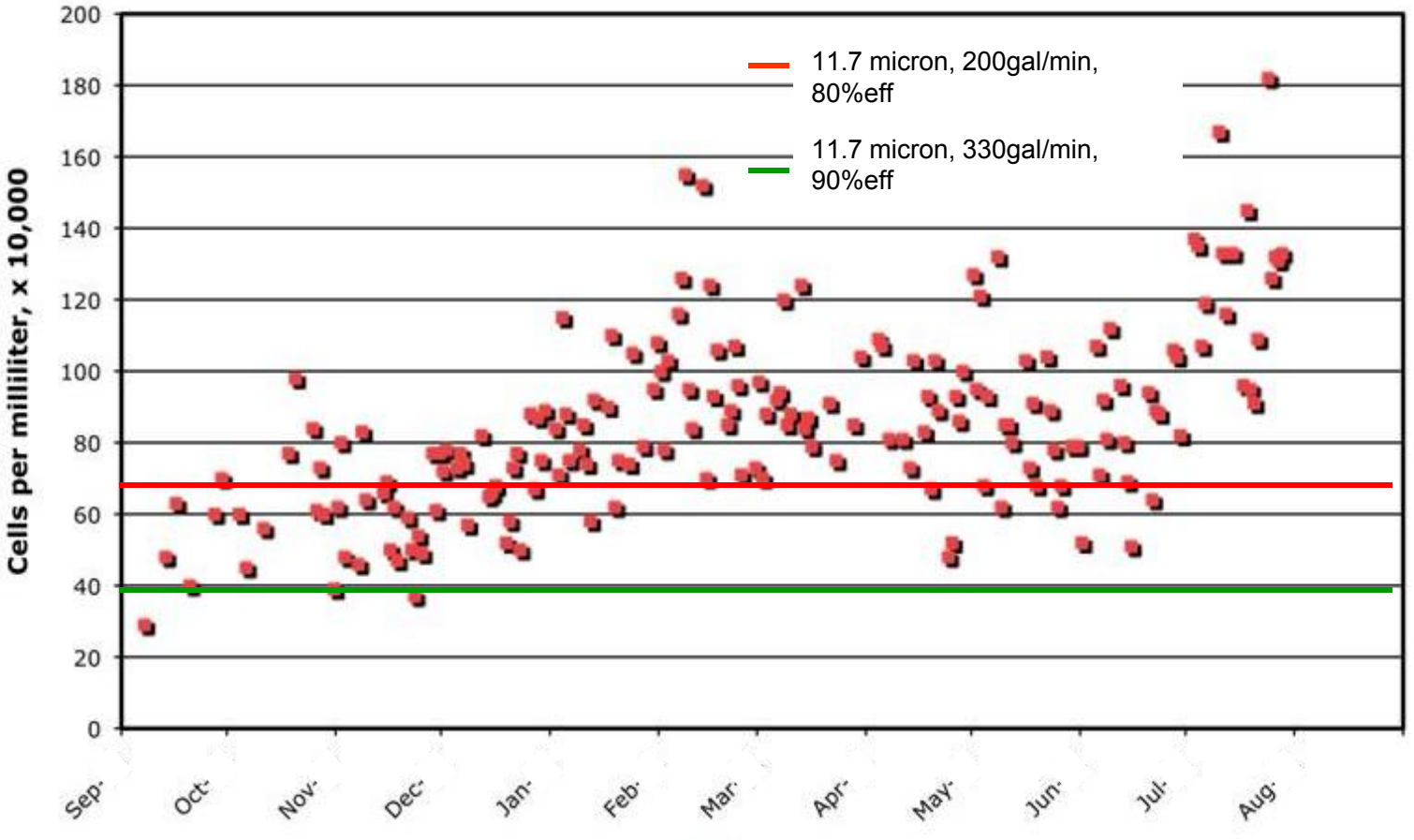
3 – Technical Accomplishments/ Progress/Results (cont'd)

Figure 4. Aquaculture pond used to feed the harvester during trials.

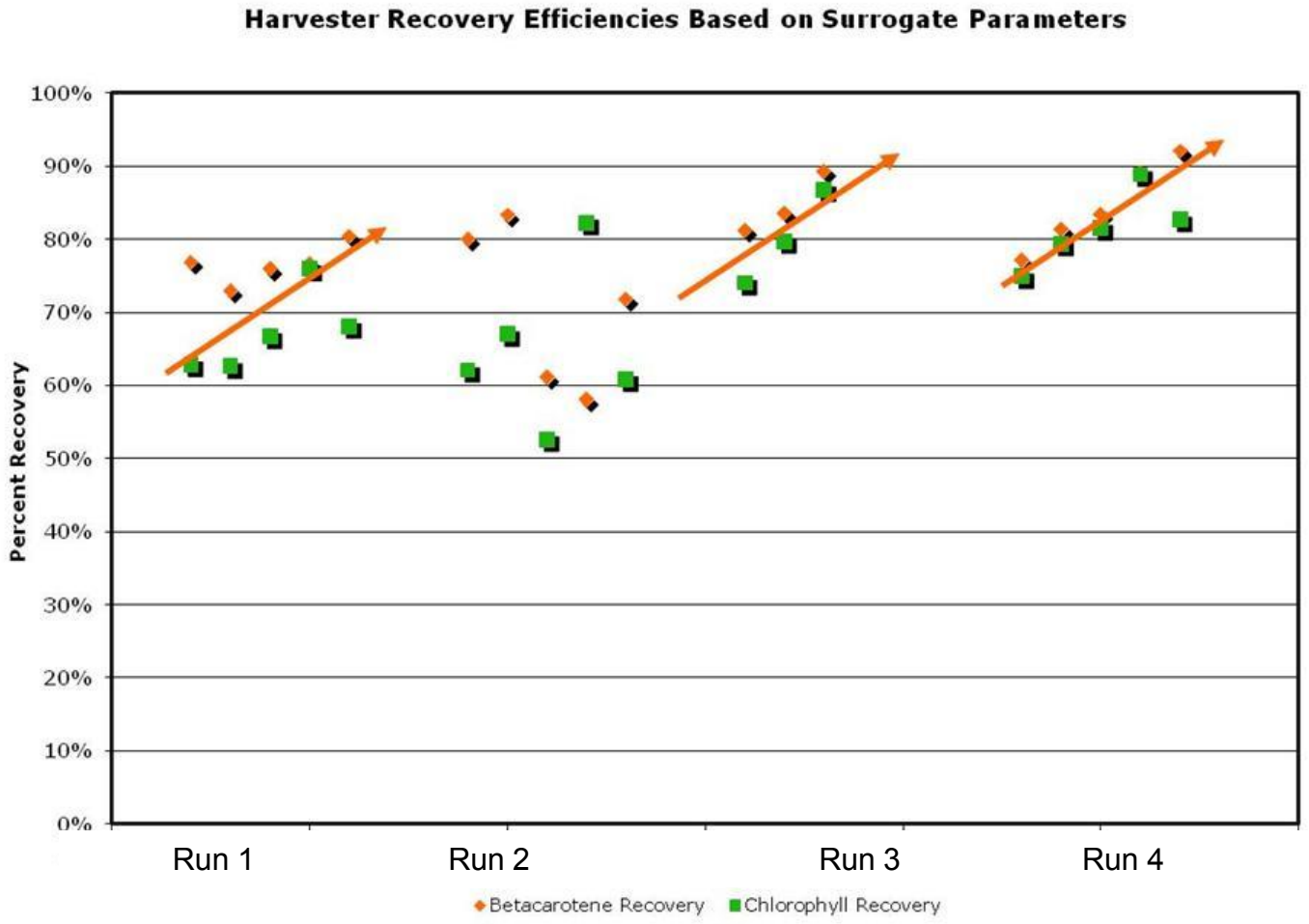
3 – Technical Accomplishments/ Progress/Results (cont'd)



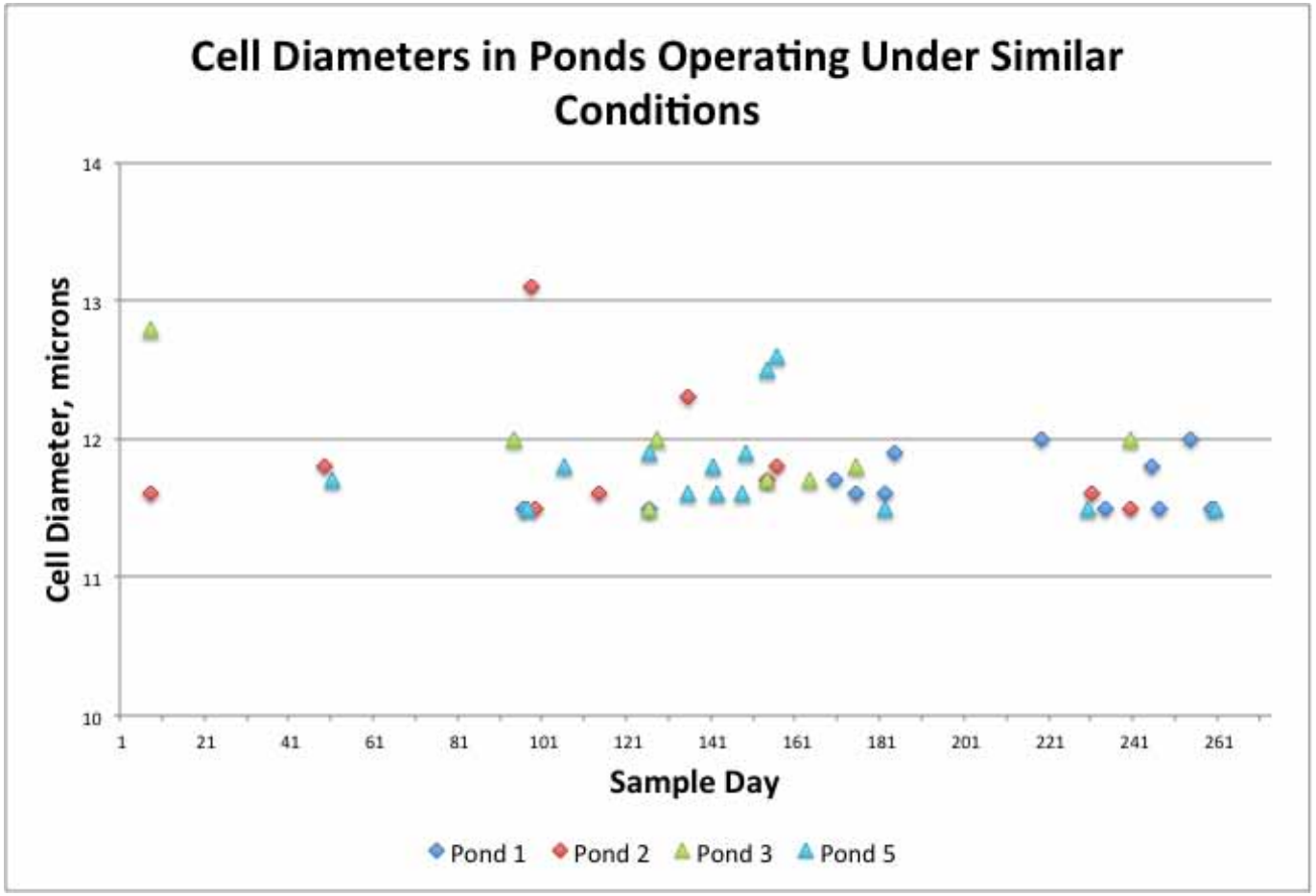
3 – Technical Accomplishments/ Progress/Results (cont'd)



3 – Technical Accomplishments/ Progress/Results (cont'd)



3 – Technical Accomplishments/ Progress/Results (cont'd)



4 – Relevance

- This project fits the goals of the BETO MYPP by demonstrating algal harvesting technology that is commercially scalable and operates at an acceptable energy usage level.
- The off-take agreement with Neste Oil (world's largest producer of renewable diesel) is a significant step forward for the algal bioenergy industry, because it validates that the harvesting technology can produce algal oil of sufficient quality at a price point that is commercially viable.
- The strategic partnership agreement with ABB (global leader in power and process automation) supports the technical approach used and facilitates its global deployment.

Summary

- **Goal 1:** Demonstrated a prototype algal harvesting process at a sufficient scale (>300,000 U.S. gallons of algae culture processed per day = 208 gal/min or [787 liters/min=47,242 liters/hour]) to facilitate commercial scale-up.

- **Goal 2:** Demonstrated that the energy intensity of the harvesting process does not exceed 10% of the energy content of the algal biomass being processed.

- The off-take agreement with Neste Oil is a significant step forward for the algal bioenergy industry, because it validates that the harvesting technology can produce algal oil of sufficient quality at a price point that is commercially viable.
- The strategic partnership agreement with ABB, Inc. supports the technical approach used and facilitates its global deployment.

Additional Slides

Publications, Patents, Presentations, Awards, and Commercialization

- Publications, Patents, Presentations, Awards
  - Recognized by the DOE/BETO as one of top five algal biomass accomplishments in 2014
  - Presented at the plenary session of the 2014 Algal Biomass Summit in San Diego, CA
- Commercialization
  - Successful results support raising Series A equity investment
  - Leveraging oil off-take agreement to secure protein off-take agreements for both human and animal nutrition – engaged in multi-party commercial evaluations of technology and products
  - Evaluating North American production locations to support commodity-scale technology deployment for secured off-take agreements
  - Engaged international bank for project finance structuring

The Energy Content of the Algae
(on an ash free dry weight basis)

- The heat of combustion, $h = (R/7.89 + 0.4) \times 1{,}000$
- $R = 100 \times [(\%C \times 2.66) + (\%H \times 7.94) - (\%O_2)]/398.9$
- If a typical algal cell is composed of 56.0% carbon, 8.1% hydrogen, and 31% oxygen, all expressed in percentage of ash-free weight, then: R=45.7
- And, $h = 6{,}200$ cal/g = 24.6 BTU/g = 0.00966 hp/g

- Benefield, L. D. and C. W. Randall (1980) "Chapter 6: Treatment Ponds and Aerated Lagoons," in *Biological Process Design for Wastewater Treatment*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1980.