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Track: Air Pollution & GHGs | May 6, 2025

Advanced LED-lit Photobioreactors Deliver CCU While Maximizing Returns

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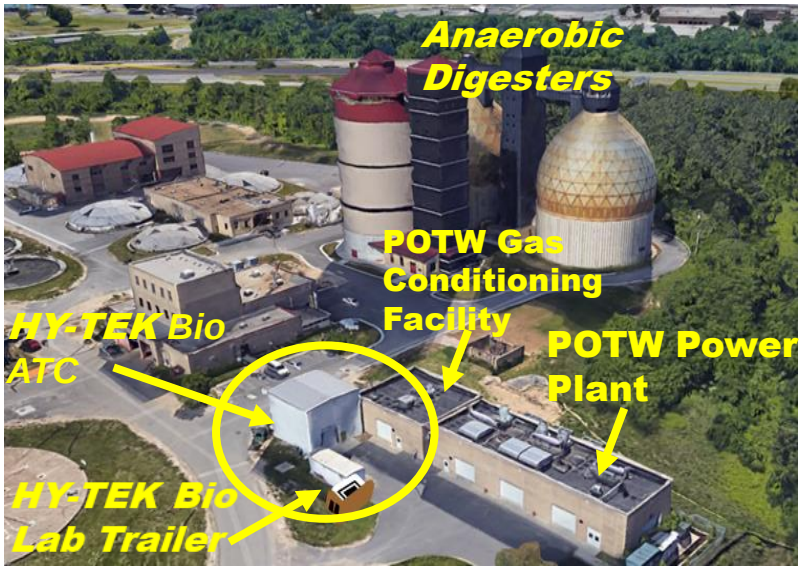
Presentation Outline

Who Are We? ESSRE Consulting & HY-TEK Bio, LLC.

Role: Technology Solution Providers - Resource Recovery of Waste C and Nutrients

- **Privately held – Headquartered in Sparrows Pt., Maryland near Baltimore; Algae Test Center located at Baltimore's Back River Waste Water Treatment Plant**
- **Technology and Project Developers of Microalgal Integrated Biorefinery Systems designed for concurrent CDR and CCU**
- **Mitigates up to 5% of a 3 MW Power Plant that combusts Anaerobid Digester Biogas since July 2013**
- **CO_2 and NO_x removal efficiencies of 100% respectively, from 10L, 500L and 6800L Photobioreactors**
- **Conversion commercialization pursuits focus on DHA/EPA, Carotenoids, Biofuels or Biochar**



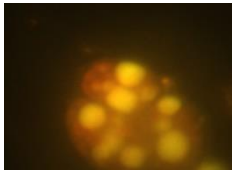
WRRF CO_2 Capture and Reuse Project
C, N & P, O_2

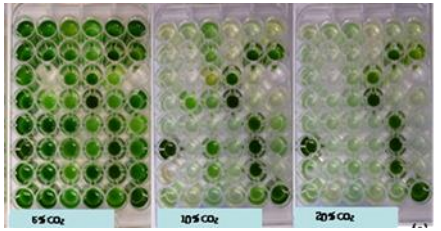
Mass Cultivation of Microalgae in Photobioreactors – Net Negative C Operations

$$106CO_2 + 16HNO_3 + H_3PO_4 + 78\,H_20 \xrightarrow{\text{light}} C_{106}H_{175}O_{42}N_{16}P + 150O_2$$

Technology Overview FIVE KEY COMPONENTS TO Carbon Recovery/Reuse & GHG Mitigation

1. **ALGAE – A unique strain of algae indigenous to the Chesapeake Bay that rapidly consumes NOx, CO_2 GHGs and other emissions; *thrives at up to 100% CO_2 levels;* and, is high in lipid oil and other marketable products**
2. **CONTAINMENT – 20' tall, bubble column photobioreactors in lieu of ponds, raceways**
3. **LIGHTING – Employs a patent-pending high intensity LED Grow Light System that optimizes wave spectra, photointensity, photoperiod with a "flash effect" that enhances photosynthesis to maximize algal system yield**
4. **GAS INJECTION – A patent-pending gas injection system that assures rapid CO_2 dissolution in one tall cultivation vessel for enhanced algal growth**
5. **NUTRIENT – Uses a patent-pending process that converts animal manure or other biomass into a concentrated nutrient solution for cost-saving maximum growth and density of the algal strain.**





DOE and State Funded Technology Advances – 2017 thru Present

- A breakthrough technology that can mitigate **100%** of CO_2, NOx and provide Carbon Capture & Utilization (CCU).
- A CCU solution for any source of CO_2 (landfill, WWTP, power plant or other carbon emitter).
- **"Natural" NOx mitigation for profit without the use of chemicals or catalysts**
- An innovative **LED Grow Light System** which increases algal growth, reduces heat and power consumption and increases the carotenoid content.
- **Modular/scalable design speeds implementation and works with any generating capacity - from small landfills to large power plants.**
- Over 12,000 hours of operating experience backed by credible third party validation.
- **CCU: Produces algae, commodity oxygen and high-value bioproducts which generates significant revenue sharing opportunities.**

Algal System Technology/Flue Gas Conditioning

FLUE GAS

Flue gas is captured using a slipstream and cooled using Waste Heat Recovery Units (not shown)

FLUE GAS FILTRATION

Simple condensate trap cools gas & water to 85F and traps any particulates

FLUE GAS COMPRESSION

Flue gas is fed to a Liquid Ring Pump to minimize heat of compression. The water is separated from the compressed flue gas which is then directed to the photobioreactors (PBRs)

WATER CONDITIONING

Liquid Ring Pump recirculating water is neutralized to pH 7 SU and cooled to <70F for re-use as the compressor seal and PBR makeup water with nutrients added

Microalgae Cultivation Technology/Process

FLUE GAS INJECTION

A special gas sparger was developed in-house to ensure rapid transfer of gas chemistry to the culture using micro- bubbles that increase light penetration and enhance tall column mixing throughout

GROWTH ENHANCEMENT

Advanced LED lighting technology developed in-house to enhance growth and nutritional value of the algae via proprietary lighting strategies that "photo-stress" the algae and reduce energy consumption

CULTURE HARVEST

When the algae gets too dense for light penetration, the automation drains 10% of the tank to thin out the culture to get more light

CULTURE HOLDING

Harvested algae is centrifuged (not shown) to concentrate the algae into paste product for conversion. Centrate is recirculated to the PBRs.

Why Algae? - Host of Bioproducts

- Algae and algae oil is used in the following products (partial list)

- ✓ **Nutraceutical products,** eye nutrients, Omega-3 Fatty Acids, DHA-EPA
- ✓ Skin conditioners
- ✓ Cosmetic and paint thickeners

- ✓ Bioplastics

- ✓ Animal and human food supplements - **PROTEINS**
- ✓ The HY-TEK Bio algae *s.HTB-1* can bring > **$16/lb** net value market pricing

- ✓ 90-95% **Oxygen** from photosynthesis is a reusable marketable commodity
- ✓ Direct replacement for Palm Oil

- ✓ **Biochar Soil Amendment**

Carbon Reuse via Microalgae

Biofuels

- Biodiesel, Renewable Diesel, and SAF

Bioproducts

- *Carotenoids –> Pigments, Nutraceuticals*
- Proteins
- Sugars/Starches
- *Soil amendment/fertilizer - Biochar*

Commercial Project Overview: Landfill Energy Project Site

- Active or Closed Landfill
- Active Gas Collection System
- CHP or RNG
- 400 scfm = 8 Photobioreactors
- Containerized Modular Microalgal Biorefinery System

Other Beachhead Targets:

- WWTP Anaerobic Digester Biogas Utilization
- Farm Manure Digesters

Algae Performance and Production/Financial Metrics

- **Growth & Harvesting – *sHTB1***
  - Specific Growth = <1 day
  - Culture Density = 5 g/L
  - 75 lbs/day/bioreactor
  - Oil Lipid Content = 35%
  - Areal Utilization = 40 g/m^2/day (DOE min. threshold 20 g/m2/day)
- **Production & Financial Projections (10, yrs., 8 Photobioreactors)**
  - 600 lb. Algae per day
  - Daily Algae Revenue = 600 * $16/lb = $9600/day
  - Annual Revenue = average $2.67M
  - Initial Capital Investment = approx. $3.6M
  - Simple Payback Period = < 3 years and Annual ROI = >50% at breakeven pt.
  - IRR = >28%
- **Algae Revenue Drives the Profit Engine for Owner/Operators & Technology Providers**
- **Multitude of Product Markets – Highest Valued is Lutein, $1000/kg**

Algal-Economics

✓ Net Market Value per Ton

- ✓ **$16/lb Microalgae = $32,000/Ton**
- ○ **$0.50/lb Gasoline = $1000/Ton (@$3.07/gallon)**
- ✓ **$450/lb Lutein = $900,000/Ton**
- ○ **$0.46/lb Renewable Diesel = $920/Ton @3.73/gallon**
- ○ **$80/MT Carbon Credit = $72.20/Ton**

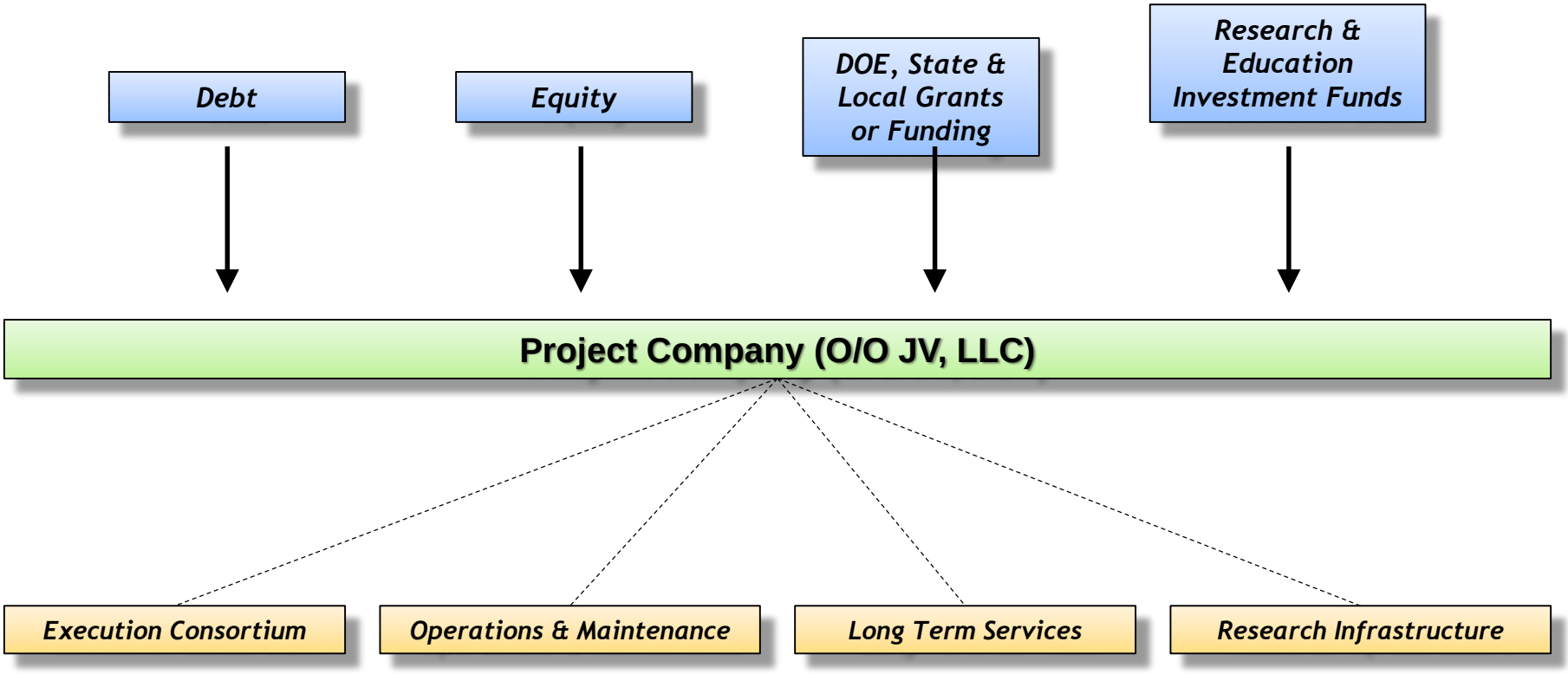
Commercialization Setbacks

- Covid-19 Pandemic
- PBR Vessel Rupture

Business Model Revenue Sharing Components

- ✓ **Land (Space) Annual Rental Fee**
  - At or Above Fair Market Rates
- ✓ **Microalgae Biorefinery Facility Electric Bill**
  - Parasitic load paid back at premium above established PPA rate
- ✓ **Project Credits, O & M Credits**
  - Carbon credits, job creation credits go back to site Owner/Host
  - If O/O takes on O&M creates new jobs and avoids cost of 3rd party O&M profit margins

Commercial Demonstration Project: Structure Overview



- O/O or CCU Site
- HY-TEK Bio
- ESSRE Consulting
- O/O A/E
- O/O GC

- O/O or CCU Site
- A/E or GC
- HY-TEK BIO

- O/O or CCU Site
- 3rd Party O&M
- HY-TEK BIO/ESSRE

- DOE, USDA, USEPA, Others
- Universities
- Consultants

Microalgae Benefits

Air Quality Improvement

- Priority air pollutant NO_x to Non-Detect and CO_2 GHG emissions reduction
- Reduce O/O carbon footprint and carbon footprint

High Purity O_2 Gas Production

- Commodity Gas - additional sales revenue
- Replace combustion air for reduced air emissions and improved heat rates

Concurrent CDR and CCU

- *sHTB1* thrives in high CO_2 gas streams – sequester <100% CO2 to grow algae for profit
- Biogas to RNG pipeline quality provides separated CO_2 to grow algae for profit

CCU, NOx & GHG Mitigation via Microalgae is Independent of Utilities Operations

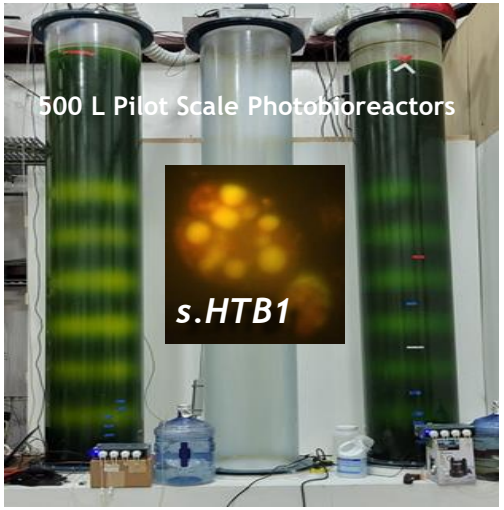
Algae Facility Installation and Operations Are Paid for by Algae Revenue

Excess maintenance (and costs) for engines to comply with NO_x emissions eliminated

Job Creation

Review Points

Digesters/Landfills
Biogas Engine Exhaust
LFG Engine Exhaust
RNG Waste CO2 Tail Gas



Recycled N &P from Manure, Wastewater, Digestate or Landfill

Lutein

Key Takeaways and Action Plans

- ✓ **Concurrent CDR and Carbon Capture & Utilization (CCU) via a commercial scale Microalgal Integrated Biorefinery**
- ✓ **Our clean energy solution is break-through technology, has the potential to eliminate 100% of the CO_2 (GHG) emissions & NOx emissions from flue gas exhaust it processes while generating high market value algae end products.**
- ✓ **Beachhead target is CO_2 content of biogas or landfill gas regardless of utilization: CHP (engine exhaust) or RNG (waste tail gas from purified biogas/LFG. CO_2 concentration range from 3% to 98%**
- ✓ **Non-potable water sourcing**
- ✓ **Provides O/O opportunities for new revenue streams driven by Lutein**
- ✓ **Provides design that is modular and flexible as flue gas varies over project life**
- ✓ **Seeking an Alpha Commercial Demonstration, 4 or more Photobioreactors (200 scfm flue gas)**

GHG Calculator I Algae

$$106CO_2 + 16HNO_3 + H_3PO_4 + 78\,H_2O \xrightarrow[\text{(light)}]{} C_{106}H_{175}O_{42}N_{16}P + 150O_2$$

- **Almost half of the algae by weight is C, hence**,
  - **1 Ton of Algae "FIXES" 1.83 Tons of CO_2**

- **100 PBRs will mitigate 1238 Metric Tons of CO_2 annually**
  - **$99,000 pa @ $80/MT CO_2 carbon credits**

- **The CO_2 emissions reduction from 10 Algae Facilities is equivalent to**:
  - **15 acres of trees planted**
  - **520 cars removed from the road**
  - ***795 tons of synthetic N fertilizer (as A-NH3)****
  - ***6,008 tons of synthetic P fertilizer (as TSP)****

* Blonk Consultants Report, GHG Emissions of N, P and K Fertilizer Production A. Kool, M. Marinussen, and H. Blonk , November, 2012

GHG Calculator II AD Biogas & LEDs

- **Data from American Biogas Council 2025 Conference**
  - **The U.S. biogas market is a $37.6 billion industry**
  - **1,180 water resource recovery facilities use anaerobic digesters**
  - **609 anaerobic digesters on farms**
  - **583 landfill gas capture projects**
  - **113 stand-alone food waste biogas systems**

- **GHG emissions reductions from Horticulture LEDs***
  - **If all indoor horticultural lighting were converted to conventional horticultural LED, annual lighting consumption would be reduced by 34%:**
  - **9,591 GWh to 6,307 GWh pa and applying our GROW Light systems would reduce this potentially another 80% to 1261 GWh**
  - **Total potential savings, 8330 GWh which represents *ca*. 3.07 MMT CO_2eq pa (2020)**
  - **In comparison, Agreena, European carbon credit startup is working with more than 2,000 farmers and hopes to issue 1 million credits pa for 1st 2 years**

* US DOE Report - Energy Savings Potential of SSL in Agricultural Applications (2020)

Questions? Discussion

1. DOE Myth Busters: a) LED lights too expensive vs. natural sunlight
   b) Commodity Biofuels & Bioproducts vs. Niche Products

2. Algae Feed/Food or Fuel? 3. Gigatons vs. Megatons – CO_2 Reduction (CDR)

4. Transfer LED lighting strategies to CEA grown leafy greens for Lutein

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