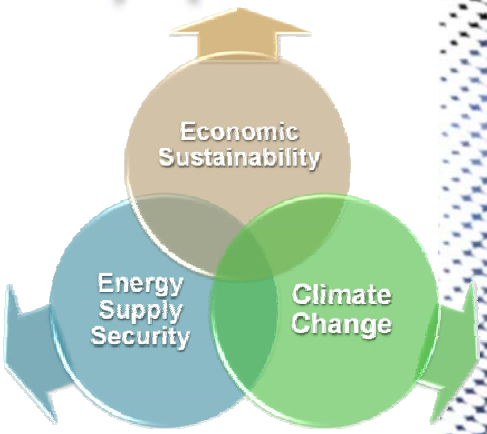
NATIONAL ENERGY TECHNOLOGY LABORATORY



Carbon Abatement Employing Algae

Michael Knaggs, Director - Fuels Division
Office of Coal Power R&D
Strategic Center for Coal
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U.S. DOE Algae R&D

- **The Department sponsors applied algae research primarily in two programs:**
  - Energy Efficiency and Renewable Energy (EERE)
  - Fossil Energy (FE) Carbon Capture and Sequestration
- **EERE**
  - Focus is renewable fuels
- **FE Program sponsorship limited to a single, Recovery Act-funded program**
  - Industrial Carbon Capture and Sequestration (ICCS)
  - Focus is carbon management via beneficial use of CO_2

Industrial Carbon Capture & Sequestration

- **2009 American Recovery And Reinvestment Act**
  - Provisions for Fossil Energy Research & Development
- **"…$1,520,000 for a competitive solicitation for a range of industrial carbon capture and energy efficiency improvement projects, including a small allocation for innovative concepts for beneficial CO2 reuse"**
- **FOA 0000015 issued June 8, 2009 with 2 Topics**
  - Technology Area 1: Large-Scale Industrial CCS Projects from Industrial Sources (~$1.42B)
  - **Technology Area 2: Innovative Concepts for Beneficial CO_2 Use (~$100M)**

ICCS FOA Topic Area 2 Results

- **Several dozen applications received and evaluated**
- **12 Selected for Phase I Awards – 5 of these classified as algae or algae-related**
  - **Gas Technology Institute**
  - **Phycal**
  - **Sunrise Ridge Algae**
  - **Touchstone Research Laboratory**
  - **UOP, LLC**
- **Phase I – Project Definition phase**
  - Combined DOE Value $7,019,671
- **Phase II awards to result from down-selection**
  - Renewal Applications currently under evaluation

Gas Technology Institute

- **Title:** Macroalgae for CO_2 Capture and Renewable Energy: A Pilot-Commercial Demonstration Project
- **Project Partners and/or Subcontractors:** University of California San Diego, The University of Connecticut, San Diego Gas & Electric Company, Southern California Gas Company
- **DOE Cost:** $993,284**, Total Cost:** $1,241,584**, Cost Share:** 20%
- **Summary:** The project team will grow specifically-selected varieties of fast-growing, highly productive **marine seaweeds** in non-submerged systems within greenhouse enclosures. The seaweeds will be irrigated constantly with nutrient-rich sprays formulated from a base of recycled municipal sewage effluent and added salts and micronutrients, including CO_2 and NOx from a natural gas-fired power plant.

Phycal

- **Title:** Beneficial CO_2 Capture in an Integrated Algal Biorefinery for Renewable Generation and Transportation Fuels
- **Project Partners and/or Subcontractors:** SSOE Engineering, GE Global Research, Aqua Engineers, Seambiotic, Kuehnle AgroSystems, Inc., Hawai'i Department of Business, Economic Development, and Tourism (DBEDT)

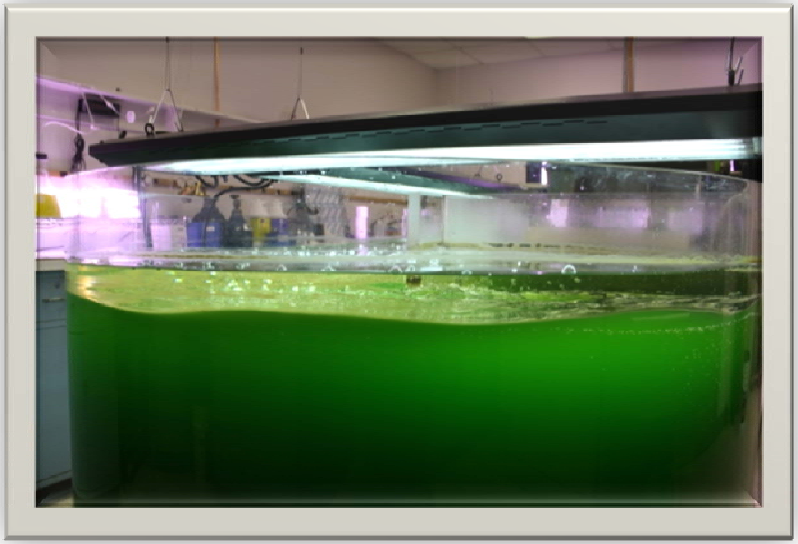
- **DOE Cost:** $3,000,000**, Total Cost:** $4,390,736**, Cost Share:** 32%
- **Summary:** The project team will feed CO_2 gas to an algal oil production process employing open raceway ponds and partially processed wastewater. Two patent-pending technologies will be integrated to form an Integrated Algal Biorefinery (IBR) pilot project. The technologies are: Olexal™, a nondestructive lipid extraction process that will reduce dewatering burden and increase productivity by returning live algae to pond after extraction, and Heteroboost™, a heterotrophic process to boost lipid production prior to extraction.

Sunrise Ridge Algae

- **Title:** Production of Algal BioCrude Oil from Cement Plant Carbon Dioxide
- **Project Partners and/or Subcontractors:** URS Group, Lehigh Cement Company, University of Texas, UOP, Houston Technology Center
- **DOE Cost:** $498,606**, Total Cost:** $623,257**, Cost Share:** 20%
- **Summary:** The project team will capture carbon in the form of algae using open raceway ponds. Harvested algae will undergo pyrolysis to produce liquid fuel and carbonaceous char. The liquid fuel may serve as a diesel fuel replacement or extender. The carbonaceous char can be burned as a fuel, displacing some of the coal that is consumed by the cement plant's kilns.

Touchstone Research Laboratory

- **Title:** Re-utilization of Industrial CO_2 for Algae Production Using a Phase Change Material
- **Project Partners and/or Subcontractors:** Cedar Lane Farms, Ohio State University (OARDC), Wheeling Jesuit University, GZA GeoEnvironmental, Inc.
- **DOE Cost:** $517,818**, Total Cost:** $647,272**, Cost Share:** 20%



- **Summary:** The project team will use a novel phase change material (PCM) residing atop a raceway pond to reduce water loss due to evaporation, conserve solar energy by reducing water temperature drop, and prevent contamination by invasive species. The CO_2 is converted into algae biomass, which is harvested and extracted for oil and conversion to fuel. The recovered lipids will be converted into biodiesel. The byproduct algae residuals will be used to perform anaerobic digestion and the biomethane that is produced will be evaluated for electricity generation.

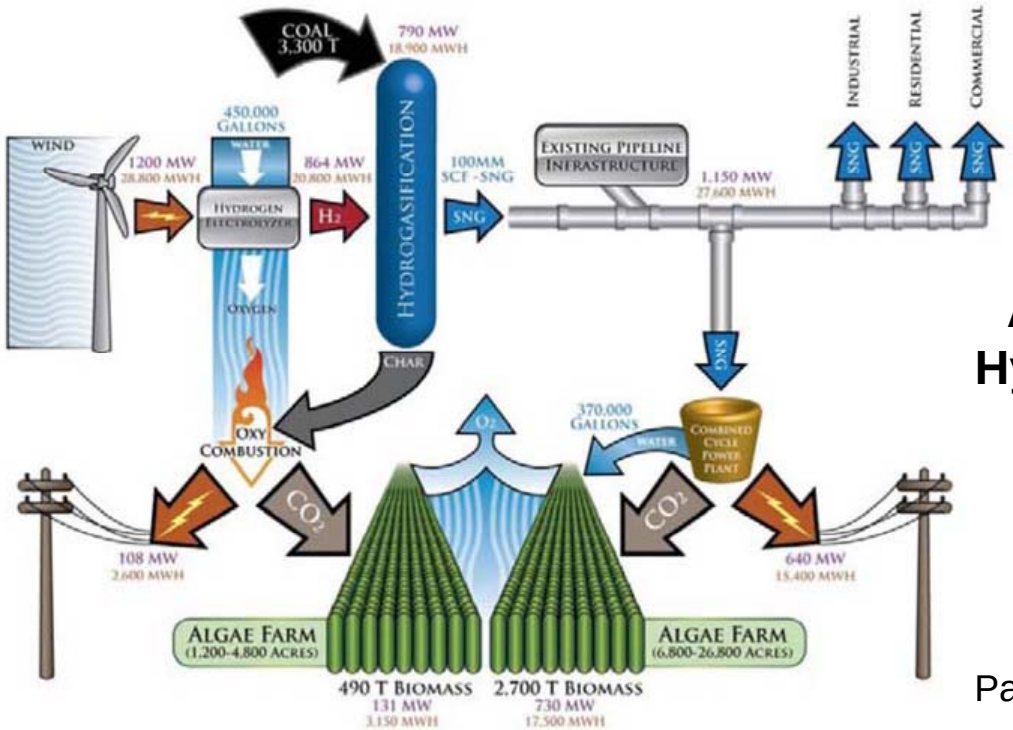
UOP, LLC

- **Title:** Beneficial CO_2 Capture for Production of Fuels, Fertilizer and Energy
- **Project Partners and/or Subcontractors:** Honeywell-Resins and Chemicals, Honeywell-Process Solutions, Envergent, Aquaflow, Vaperma, International Alliance Group
- **DOE Cost:** $2,069,869**, Total Cost:** $2,956,956**, Cost Share:** 30%
- **Summary:** The project team will capture and beneficially reuse CO_2 from exhaust stacks at the Hopewell, VA caprolactum plant through cultivation of algae in open tanks. UOP will utilize largely proven commercial technology owned by its partners to automate and integrate the algae cultivation process into the Hopewell facility.

Recent Work – Arizona Public Service

- **Title:** Development of a Hydrogasification process for co-production of substitute natural gas (SNG) and electric power from western coals
- **DOE Cost:** $15,709,770; **Total Cost:** $21,725,575; **Cost Share:** 28%
- **Summary**: Western coal is gasified using hydrogen as the reactant gas instead of oxygen (i.e., hydrogasification) to produce a high methane-content SNG. Unconverted coal from the gasifier will be sent to a low-pressure, oxy-combustion process to produce electricity. A portion of the carbon dioxide (CO2) stream from the combustion process will be compressed and recycled to convey the coal into the hydrogasifier. The remainder will be fed to an algae farm that consumes the CO2 from the process. Algae can be used as an additional fuel source or as a feedstock for biodiesel fuel production.

Recent Work – Arizona Public Service



APS Advanced Hydrogasification Process

Patent Pending

- **Accomplishments:** Tests were completed on a quarter-acre engineering-scale cultivation system at the APS Red Hawk Power Plant. In the test, flue gas from the power plant was utilized to feed a closed-system algae farm. With CO_2 being absorbed by the algae, an average algae growth of 98 grams per square meter per day ($g/m^2/d$) with a peak productivity of 174 $g/m^2/d$ was observed—indicating tremendous potential for reducing the plant size and costs previously envisioned for this carbon management process.

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