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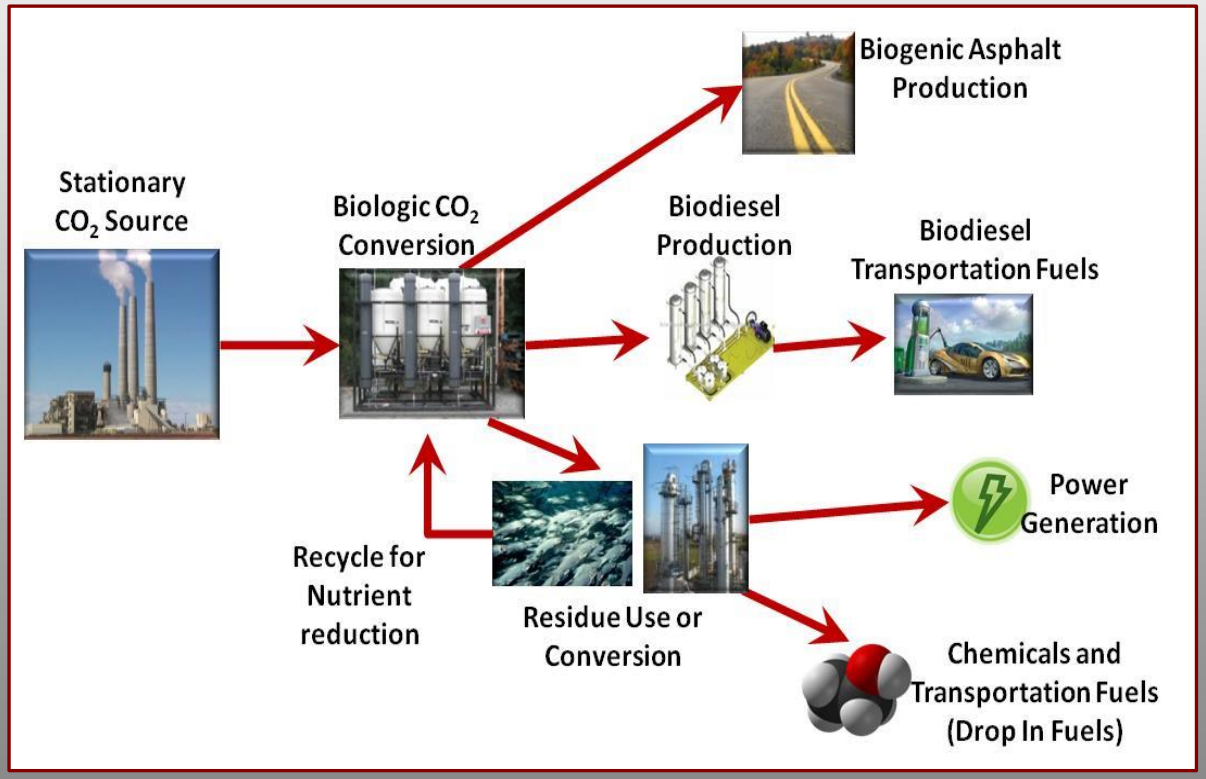
WRI's Chemoautotrophic (CAT™) Process

A Carbon Emissions Capture/Re-Use Technology



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Laramie, Wyoming

December 9, 2013

Western Research Institute

BIO Pacific Rim 2013
San Diego, CA

Bio Biotechnology Industry Organization

Presentation Outline

Outline

- Basics of the CAT™ Process
- Technology Benefits of CAT™ Process Compared to Algae
- CAT™ Application at a 100K ton/yr Emission Source
- Discussion and Questions

"Sustainability with Profitability"

Basics of the CAT™ Process

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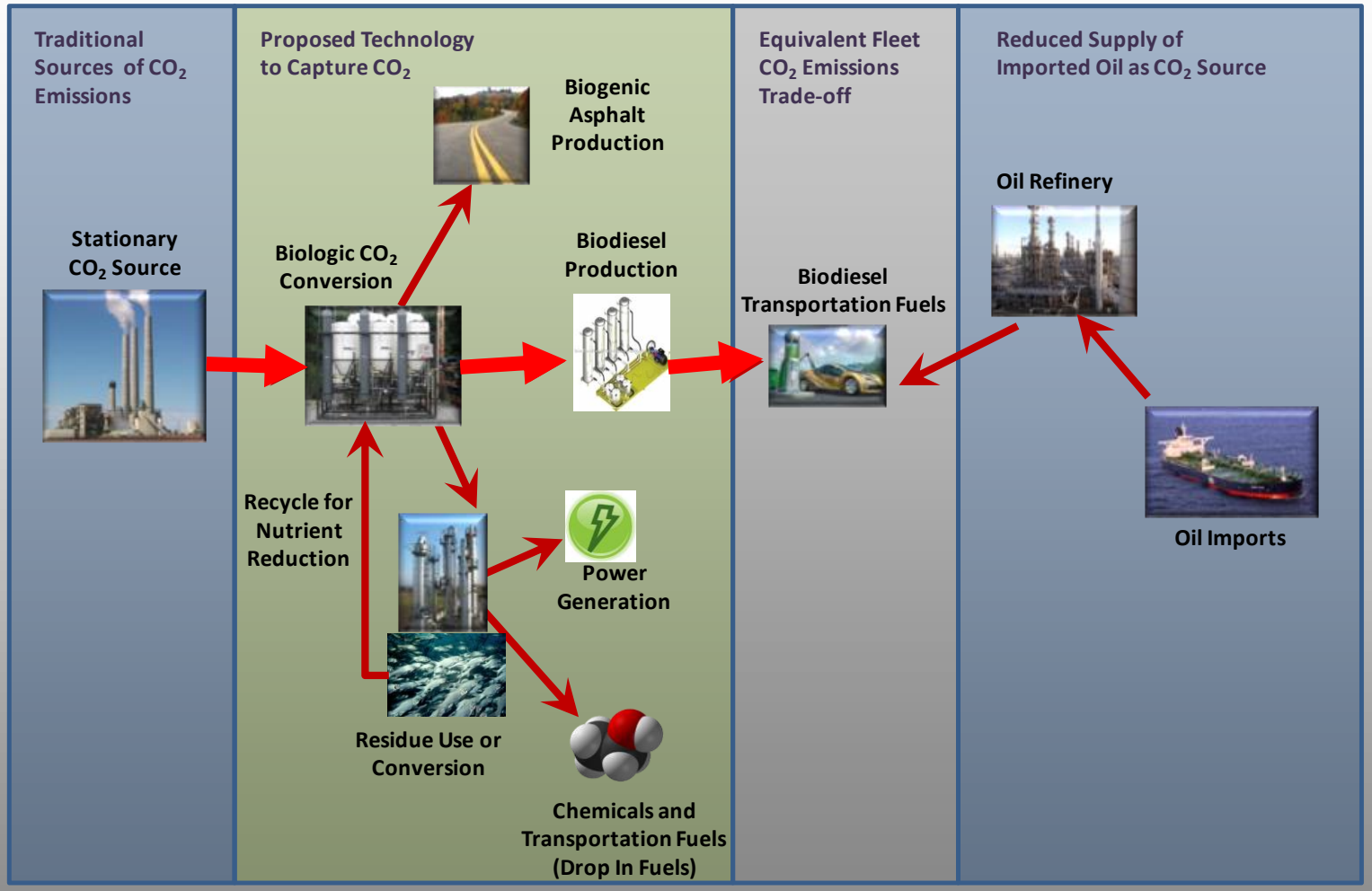
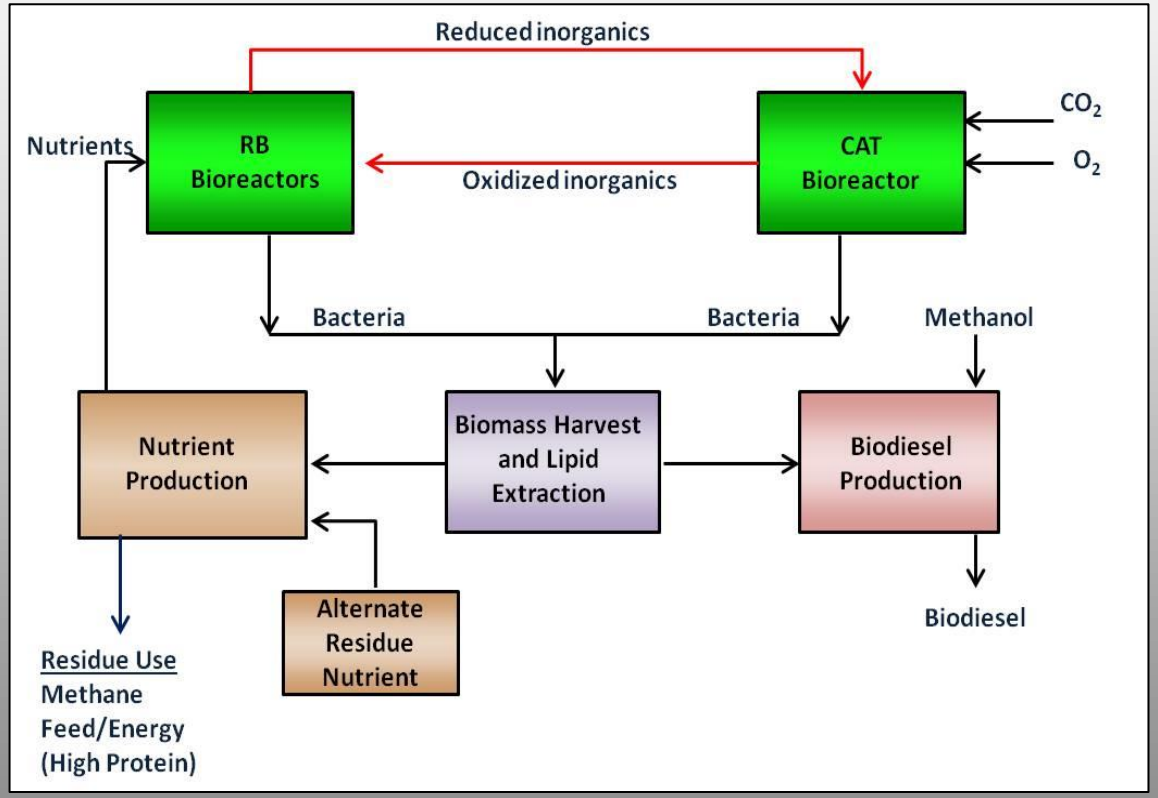
CAT™ Process Description



- CAT™ is a biological process for carbon capture and re-use as biofuels.
- Reduces net CO_2 emissions by displacing emissions from fossil transportation fuels.

How it Works

- Chemoautotrophic (CAT) bacteria to fix CO_2 and utilize inorganic material as energy source.
- Reducing bacteria (RB) reduce oxidized inorganic shuttling materials.
- Biomass harvested from CAT and RB reactors for biodiesel production
- Biomass residue is recycled for nutrients for RB.
- Unique inorganic shuttling and biomass recycle step minimizes inputs.
- Can be added directly onto an existing facility.
  - CAT and RB colocated with CO_2 source



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Technology Benefits of CAT™ Process Compared to Algae

Technology Benefits of CAT™ Process Compared to Algae

- Productivities on par with algae
- Lipid chain length consistent
- Light-independent growth
  - Reactor design
  - Land requirements
  - Climactic requirements
- Water use

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CAT™ v. Algae Productivities

Species	Volumetric Productivity (g/L/hr)	Reference
CAT™ Process		
CAT	0.015	WRI
RB	0.094	WRI
Algae		
Chlamydomonas reinhardtii	0.010	Bogen et al., 2013, *Bioresour. Technol.* **133**, 622-626.
Chlorella vulgaris	0.042, 0.25	Morita et al., 2000, *Biotechnol. Bioeng.* **69,** 693-698., Kong et al., 2013, *Biotechnol. Bioeng.*
Dunaliella spec (SAG 48.89)	0.0045	Bogen et al., 2013, *Bioresour. Technol.* **133**, 622-626.
Monoraphidium terrestre (SAG 49.89)	0.015	Bogen et al., 2013, *Bioresour. Technol.* **133**, 622-626.
Scenedesmus costatus	0.006	Bogen et al., 2013, *Bioresour. Technol.* **133**, 622-626.
Cyanobacteria		
Arthrospira platensis	0.06625	Carlozzi P., 2003, *Biotechnol. Bioeng.* **81**, 305-315

Lipid/Product Characteristics

Fuel Type	Major Components	Properties	Potential Advanced Biofuels
Gasoline	C_4-C_{12} hydrocarbons Linear, branched, cyclic aromatics	Octane number (87-91) Energy content	Butanol, isobutanol, short-chain alcohols, short branched-chain alkanes
Diesel	C_9-C_{23} hydrocarbons Linear, branched, cyclic aromatics	Cetane number (40-60) Good cold properties	Fatty alcohols, alkanes, linear or cyclic isoprenoids
CAT Bio-Diesel	C_9-C_{23} hydrocarbons have been defined making it similar to diesel composition	Cetane number and other properties yet to be defined	Advanced fuels and bio-products not yet defined.
Jet Fuel	C_8-C_{16} hydrocarbons Linear, branched, cyclic aromatics	Heat density Very low freezing temperature	Branched Alkanes, linear or cyclic isoprenoids

Adapted from Peralta-Yahya, OP.P., et al., Nature, 2012.

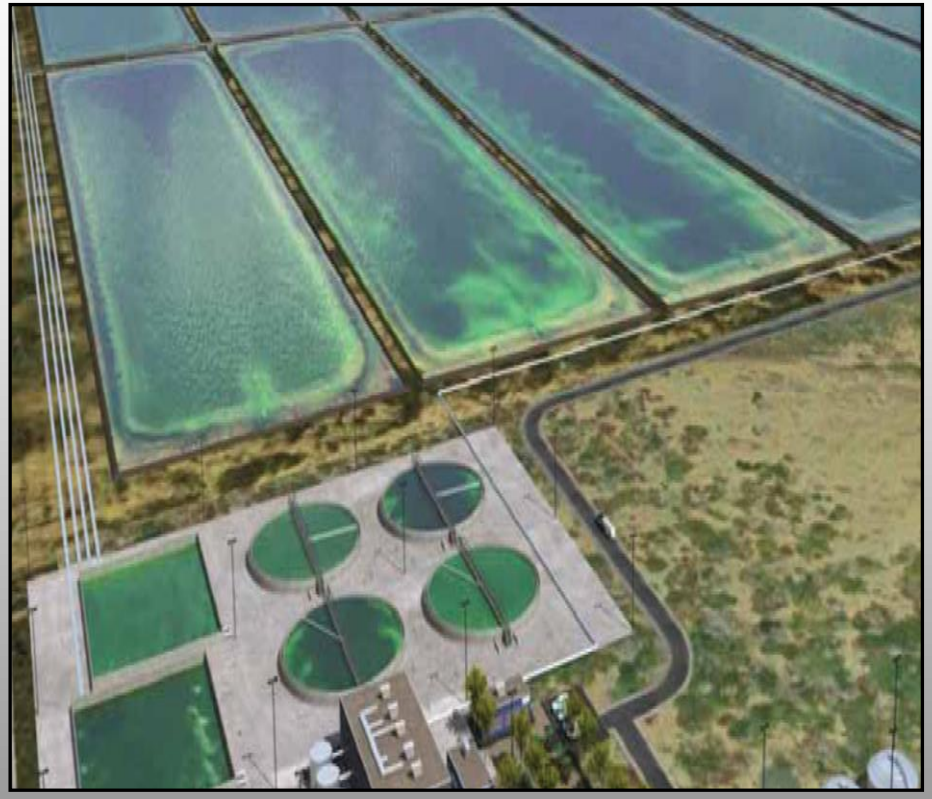
Land and Water Requirements

Plant Size and CAT™ Plant Footprint

- Estimated land necessary to generate lipids for 1.5 million gallons biodiesel crude
  - Algae-based processes: 300 acres
  - CAT™ process: 2.5 acres
- This reduction in footprint results from the lack of need for sunlight and deployment of large reactors buried in part underground.

Water Use

- Significantly less water needed for CAT™ process since reactors are closed and water can be recycled.



Sapphire Energy, one of nine companies selected by DOE for a demonstration–scale biorefinery project, is building an integrated algae-to-energy farm in Columbus, New Mexico. (Artist's rendering courtesy of Sapphire Energy)

Key Comparisons

	CAT™ Process	Algae
Productivities	On par with algae	On par with CAT
Reactor Type	Closed reactors, commercially available	Open raceway ponds, high surface area photobioreactors
Climatic Requirements	No particular requirements. Reactors may be insulated or buried to maintain temperature	Reduced performance in climatic extremes or locations with reduced sunlight. Reactors may require heating
Land Requirements	Relatively small footprint due to deep cylindrical reactors. A 95-98% reduction is estimated for larger CO_2 sources.	Large foot print, productivity maximized when reactors are no greater than 10-15 cm deep
Water Use	No evaporative losses	High evaporative losses

100K tons/yr CO_2 Emissions Source

CAT™ Application at 100,000 tons/yr CO_2 Emission Source

- Assumes 90% carbon capture
- Biodiesel production: ~125,000 bbl/yr
- Preliminary assessments:
  - Capital can be paid off in 2-3 years (not including capital for biodiesel plant)
  - Selling price of biodiesel under $3/gallon

Summary

- CAT™ Process is non-photosynthetic carbon capture and re-use process
  - biodiesel, others
- Economically viable (selling price of biodiesel under $3/gallon)
- Benefits over other systems
  - Closed system – no evaporative losses
  - Deep, cylindrical reactors can be partially buried
    - Small footprint (95-99% reduction compared to open ponds)
    - Appropriate for a variety of climates
  - Synthetic symbioses, nutrient reactor to recycle materials and reduce inputs

CAT™ Process Contact Information

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Funding

DOE Contract DE-FC26-08NT43293