SAND2006-5361C

# "BIOFAC"

**September 12, 2006**
**Madrid, Spain**

**Darryl Drayer**

## The BioFuel Factory

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

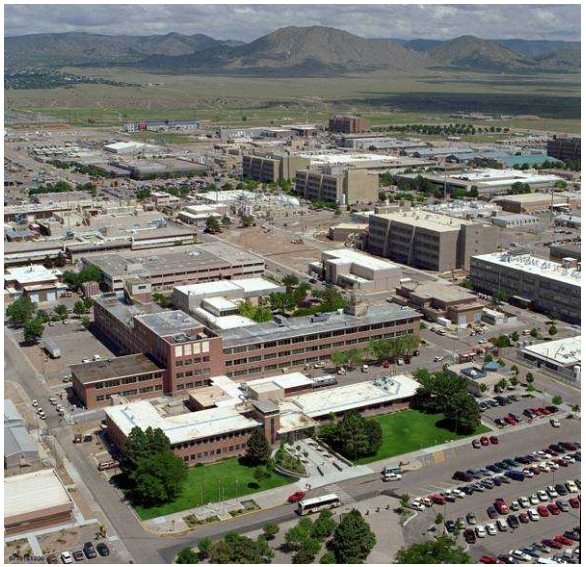
# Sandia National Laboratories


- **Core Purpose:** to help our nation secure a peaceful and free world through technology.

ACG Advanced Concepts Group

Sandia National Laboratories

# Distributed Facilities to Meet National Needs



Albuquerque,
New Mexico

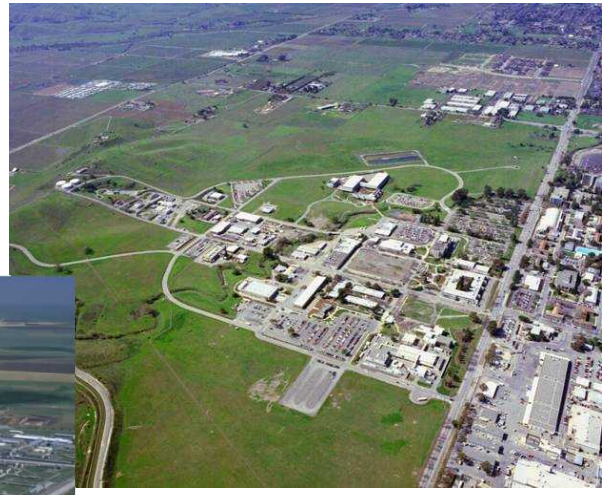
Kauai Test Facility,
Hawaii

Tonopah Test Range,
Nevada

Yucca Mountain,
Nevada

WIPP, New Mexico

Pantex, Texas



Livermore, California

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# Current Annual US Fuel Consumption for Transportation

- **2/3 of total US petroleum consumption is used for transportation:**

**208.8 Billion US gallons of fuel per year**

| Fuel | Amount (Billions US gallons/year) |
|---|---|
| Motor Gasoline | 138.9 |
| Distillate Fuel Oil (e.g. Diesel) | 62.2 |
| Jet Fuel | 24.8 |
| Fuel Ethanol & Motor Gasoline Blending Components | 7 |

Source: Annual Energy Review 2004, Energy Information Administration

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# Biofac Concept: Utilize Controlled Environment Agriculture to Provide Efficient Mass Production of Biomass


Japanese Factory Production of Lettuce

Mexican Forage Production System

Commercial Tomato Production

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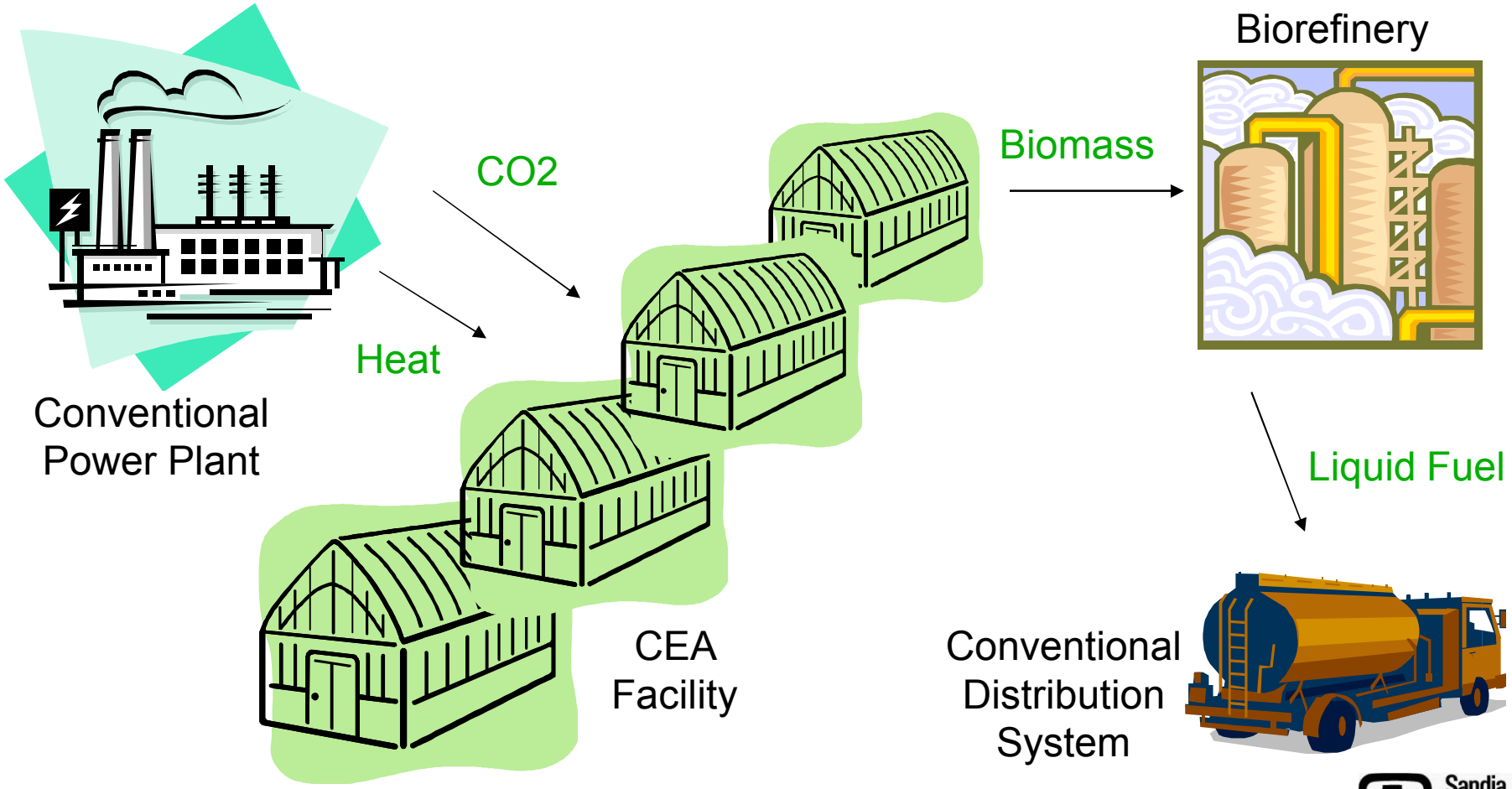
# Notional System Concept

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# Controlled Environment Agriculture Allows…

- Large volume growth
- Continuous production
- Consistent product
- Efficient use of inputs – primarily water
- Flexibility in location
- Potential for automation
- Ability to closely control process
- Easily expanded capacity
- Production only loosely coupled to environmental conditions

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# COMMERCIAL SCALE BIOFACS CAN…

- Reduce dependence on imported fuels
- Lead to distributed fuel production
- Assist in dealing with carbon emissions from conventional power production
- Utilize low grade heat from conventional power plants or other sources.

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# BIOFAC May be Well Suited to Temperate Climates

## (New Mexico, Spain)

- High Levels of Sunlight
- Mild Climate
- Potential Use of Impaired Waters
- Linkages to Existing Industries ($CO_2$ & heat from power plants)

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# Annual Liquid Fuel Production per Acre for Different Energy Crops

| Energy Crop | Fuel Production (US Gals/acre/yr) |
|---|---|
| **Soybean** | **40-50** |
| **Rapeseed** | **110-145** |
| **Mustard** | **140** |
| **Jatropha** | **175** |
| **Switch Grass** | **1500** |
| **Palm Oil** | **650** |
| **Algae** | **10,000 — 20,000** |
| **Coconut Oil** | **230** |
| **Sugar Cane** | **662** |
| **Sugar Beet** | **714** |

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# Characteristics of Energy Crops Produced in a Profitable BioFuel Factory

MIT algae bioreactor
Source: Ashley Ahearn

Switchgrass test plot at Auburn Univ.
Source: ORNL

- High fuel production per acre of land
- High utilization of and access to cheap, abundant resources as inputs (e.g. CO2, NOx, brackish water)
- Significant headroom for biotechnological improvements in fuel production and cost reduction
- Sustainable competitive advantage over petroleum products (i.e., direct costs, convenience)
- No direct competition with land, freshwater, nutrient resources for food economy
- High Positive Net Liquid Fuel Ratio (biofuel energy output/petroleum energy input >> 1.0)

**Main Contenders for Biofuel Factory Production:**

**Photosynthetic Micro-organisms and Switchgrass**

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# GreenFuel Technologies: BioFuel Start-Up

Algae bioreactor utilizing flue gas from MIT co-generation power plant.

Source: Ashley Ahearn

$$\text{Algae} + CO_2 + NO_x + \text{saline } H_2O$$

$$\downarrow \text{ sunlight}$$

$$\text{Oil + Dried Biomass}$$

$$\downarrow \text{ biorefinery}$$

$$\text{BioDiesel + Ethanol}$$

- Est. Fuel Production Density: 15,000 US gals biodiesel per acre per yr
- Co-located with a single 1000 MW fossil fuel power plant, full-scale GreenFuel bioreactor estimated to produce 40 million US gals biodiesel & 50 million US gals ethanol per year

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# Program Outline

- **Phase I – System Study**
  - Parametric study of process
- **Phase II – Process Design**
  - Design and demonstrate components of the process.
- **Phase III – Process Optimization**
  - Develop specialized plants and optimize system.
- **Phase IV – Demonstration**
  - Construct and demonstration each element of the process using optimized components and processes.
- **Phase V – Pilot plant.**

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# Sandia's Role

- Parametric analysis of process
- End to end system model
- Process development
- Overall system design
- Engineering & demonstration of system components
- Design and demonstration of automation
- Sensors, monitoring and control

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# Current Project (Internally Funded)

- Learning from past concepts
- Thinking beyond algae and cellulosic ethanol designs that are currently being pursued by private sector
- Developing concepts for biofuel factories using novel approaches
- Conducting system analysis to optimize design and determine limitation of process.

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