

# **PEMFC Power System on Ethanol**

**Caterpillar Inc.**

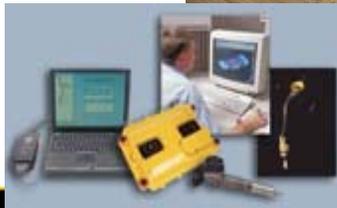
**Thomas J. Richards**



## PEM ETHANOL FUEL CELL

DOE Hydrogen & Fuel Cells 2003  
Annual Merit Review

21 May 2003



## PEM ETHANOL FUEL CELL

*In 2003, a 10-15 kW stationary PEM fuel cell system will be field tested for 4000 hours at the Williams Bioenergy's ethanol production facility in Pekin, Illinois.*

*The unit will be powered by corn-based ethanol and will produce AC power for the local grid.*

*The program examines the durability of a PEM based fuel cell system while operating on ethanol - a renewable fuel.*

*The program is a consortium among Nuvera, Caterpillar, and Williams Bioenergy with funding from DOE and the State of Illinois.*

# Ethanol: A Renewable

## Economy

The U.S. ethanol industry has grown to over 2.3 billion gallons of production capacity, with plants located in 19 states.

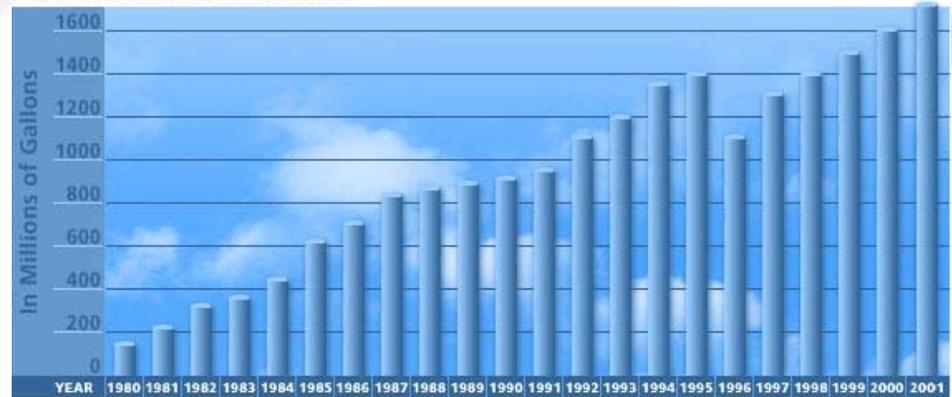
## Emission

The ethanol production process represents a carbon cycle, where plants absorb carbon dioxide during growth, "recycling" the carbon released during fuel combustion.

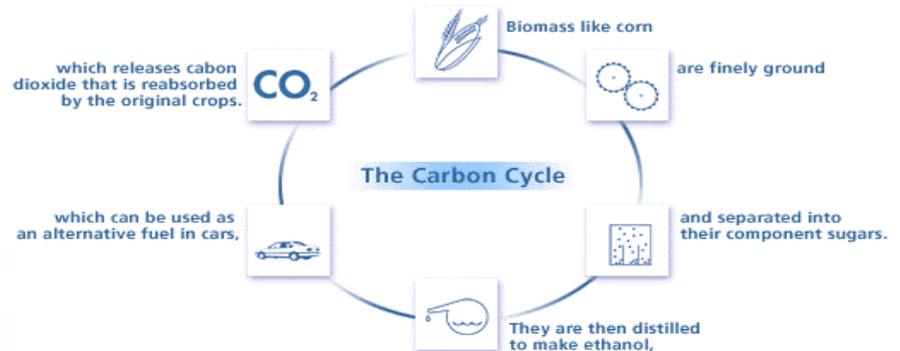
## Other Reasons

- Helping the US Energy Balance
- Fighting the Carbon Cycle creation
- Economy boost to Rural America
- State Visibility (Midwest)
- Fuel Choice for Fuel Cells???

U.S. Fuel Ethanol Production



Source: Energy Information Administration and Renewable Fuels Association



U.S. Ethanol Production Facilities



## Program Overview



### Program Partners

- Nuvera Fuel Cells
- Williams Bio-Energy



### Program Sponsors

- Department of Energy
- IL Department of Commerce & Community Affairs

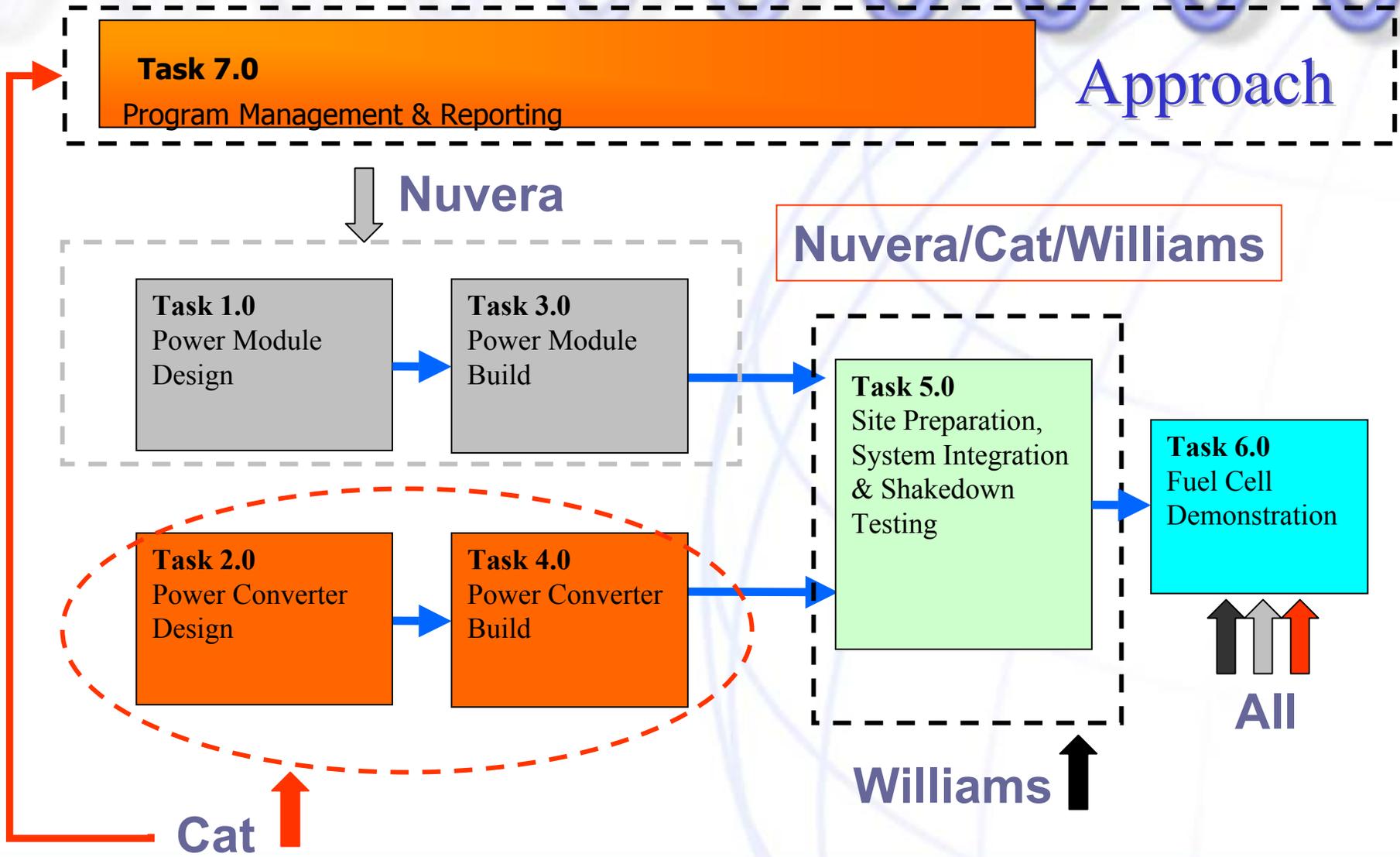


### Program Objectives

- 2-Year Cooperative Program to:
  - Design/Fabricate/Test an Ethanol-based PEM Fuel Cell
  - Demonstrate Performance and Durability: 4000 hours
  - Remove Technical Uncertainties
  - Understand Correlation and Reduce Gaps between Stationary and Transportation Application
  - Data Collection to Evaluate Economic Feasibility
  - Assess Commercial Viability of Total System

## Program Objectives

- Integrated PEM Fuel Cell System
  - Ethanol based Power Plant
  - 10-15 kW
  - 3-Phase 120/208 V<sub>AC</sub> @ 60 Hz
  - Greater than 25% Target Efficiency
  - Operability & Performance
- Demonstrate 4,000 Durability
- Data Gathering as Baseline for Feasibility
  - Economic Study
  - Transportation & Stationary Correlation



## Program Timeline (2 Years) June 2002 to June 2004

Description	1Q 02	2Q 02	3Q 02	4Q 02	1Q 03	2Q 03	3Q 03	4Q 03	1Q 04	2Q 04	3Q 04	4Q 04
PEM Ethanol Fuel Cell		√	√	√	√	→	→	→	→	→		
Power Converter Design	√	√	√	√	√							
Power Convert Procurement		√	√	√								
Assemble / Development			√	√	√							
Validate				√	√	→						
Power Module Concept	√	√										
Pow Module System Design		√	√									
Pow Mod System Build			√	√	√	→						
Site Preparation		√	√	√	√							
Field Demonstration							→	→	→			
Program Management & Reporting	√	√	√	√	√	→	→	→	→	→		
Milestones				Δ1		Δ2	Δ3		Δ4	Δ5		

## Major Milestones

Milestone	Description	Date / Status
<b>Δ1</b>	Final Design Review	November 02 / Complete
<b>Δ2</b>	Component Testing at Rated Power / Site Prep	April 03 / Complete
<b>Δ3</b>	Commence field demo	Q3-03
<b>Δ4</b>	4000 hour Utility Interactive Durability Test	March 04
<b>Δ5</b>	Final Analysis & Report	May 04

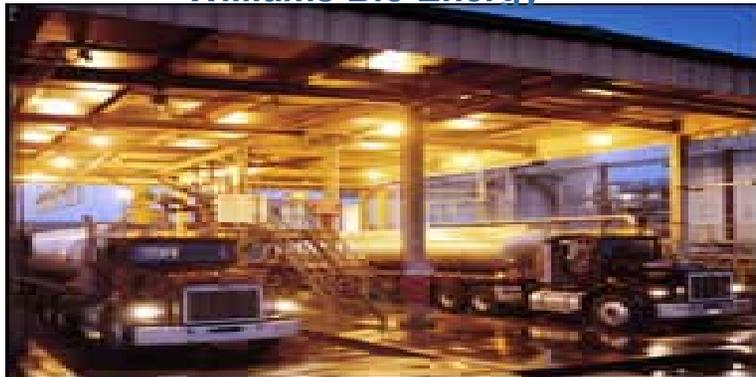
## Durability Program

### □ 2-Year Cooperative Program:

- Design/Fabricate/Test 10-15 kW Ethanol-based PEM Fuel Cell
- Demonstrate Performance and Durability: 4000 hours
- Technology and Economic Feasibility Assessment

### □ Ready to test in June 03

Williams Bio Energy



NUVERA



Ethanol Power Module (Field Unit)



Ethanol Power Module (Field Unit)



Williams' New Demo Facility

- **Dimensions (mm):**
  - **1321 H x 1372 W x 762 D (Power Module)**
  - **304 H X 610 W X 914 D (Power Converter)**
- **DC Output Voltage (V): 55 to 100**
- **Startup Time (minutes): 20-40**
- **25 to 90 % Load Response (s): 60**



Cat Power Electronics

## Accomplishments: Power Module

- ✓ Designed and built a fully integrated power system based on Model B fuel processor for ethanol operation
- ✓ Achieved afterburner free startup
- ✓ Eliminated need for reformate cleanup by eliminating ammonia formation
- ✓ Created new, robust control strategy for both reformer and fuel cell sub-systems
- ✓ Field unit demonstrated @ 11 kWe continuous output
- ✓ About 40 hr continuous run on integrated system; 125 hours total power in the laboratory

# Power Converter Accomplishments

Item	Target	Actual
Resistive load	15 kW	16 kW
Line interactive	15 KW input	15 kW input
Acceptance test	100 hour	24 hours
Efficiency	93%	90%

## **Accomplishments: Test Site**

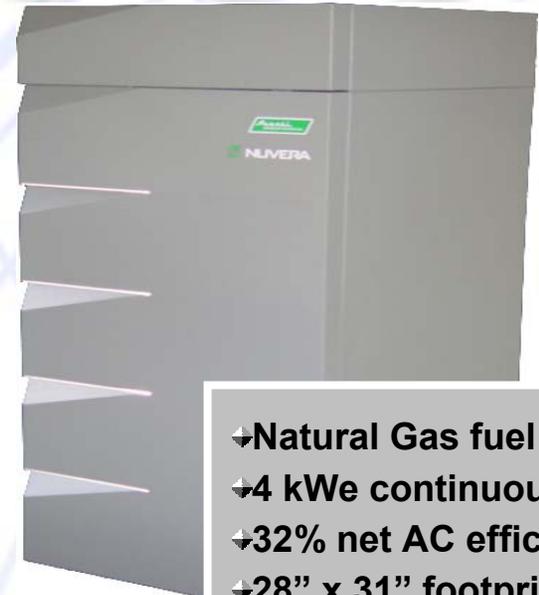
- ✓ Utility interactive
- ✓ Ethanol availability
- ✓ Data acquisition system
- ✓ Remote monitoring, data backup & internet view
- ✓ Visitor parking & observation amenities
- ✓ Hazardous operations procedures in place

# Acceptance Test Criteria

<u>Test Duration</u>	<u>Condition</u>	<u>Hardware</u>	<u>Test Type / Location</u>
1 x 24 hour continuous	≥15 kWe	Cat power converter	Factory acceptance test/ Caterpillar
3 x 24 hour continuous	≥10 kWe	Nuvera power module	Factory acceptance test/ Nuvera
500 hour combined continuous + interrupted	Any power	Nuvera power module	Factory acceptance test/ Nuvera
24 hour continuous	≥10 kWe	Power module + power converter	Factory acceptance test/ Nuvera
1 x 8 hour continuous	Max flows	Williams Utilities (fuel / water / air)	Factory acceptance test/ Williams
24 hour continuous	≥10 kWe	Power module + power converter	Site acceptance test / Williams

## Interactions

- ✓ Leverage Cat's Fuel cell commercial program in power electronics/packaging
- ✓ Leverage underground mining machine fuel cell program
- ✓ Improved Cat electronics platforms and common design to DG equipment
- ✓ Extracting lessons and processes used for New Product Introduction (NPI) in commercial applications
- ✓ Cat's life cycle cost analysis pro-format will be used in economic feasibility
- ✓ Constant communication with Nuvera's commercial 4kW natural gas power system program and individuals



- ↪ Natural Gas fuel
- ↪ 4 kWe continuous
- ↪ 32% net AC efficiency
- ↪ 28" x 31" footprint



# Contacts

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