# U.S. DOE Sponsored Study on SOFC Applications in the Transportation Industry

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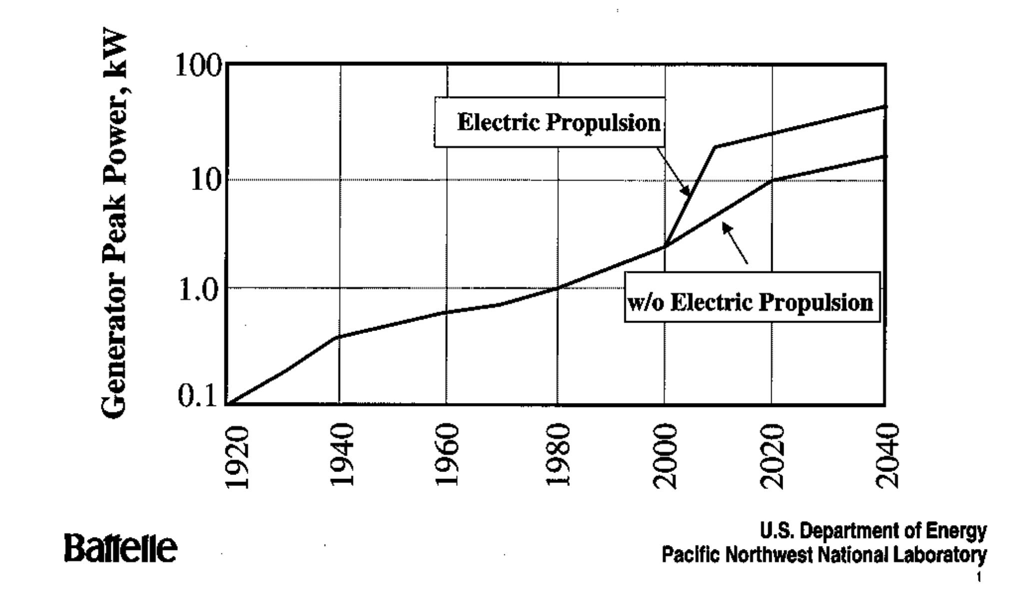
# Motivation

- Auxiliary Power Units (APU) are becoming interesting to the Automotive Industry because:
  - Power Requirements in Passenger cars are increasing
  - Anti-idling bans for trucks may be legislated



# Perceived Challenges for SOFC in Transportation

- Start-up time
- Fuel consumption during start-up
- Mechanical and thermal ruggedness
- Power density of system

# Objectives of Study

- Assess planar SOFC technology status
- Evaluate planar SOFC in transportation vehicles
- Estimate fuel savings and emissions avoidance
- Identify critical R&D issues

# Approach

- Define a "Representative" planar SOFC based on discussions with
  - Ceramic Fuel Cells Limited
  - Honeywell
  - McDermott Technology
  - Materials and System Research
  - Sulzer-Hexis
  - Rolls Royce
  - Forschungzentrum-Jülich
- Select a best suited diesel reformer based on technology from
  - Nuvera
  - Hydrogen Burner
  - McDermott
  - Johnson Matthey
  - Argonne National Laboratory

# Approach (continued)

- Conceptualize and simulate system
- Identify conventional technology or practice for a representative heavy duty vehicle
- Compare fuel consumption and emissions

# Typical Planar SOFC Characteristics

- 850°C cell average temperature
- 0.7 volts/cell
- 0.85 fuel utilization
- 100°C  cell oxidant temperature rise
- 10 cm by 10 cm active area
- System electric output is 12V DC (voltage regulator)

# Typical Fuel Processor Characteristics

- ATR selected processor
- Temperature: 1000°C

  Steam/Carbon: 3.1

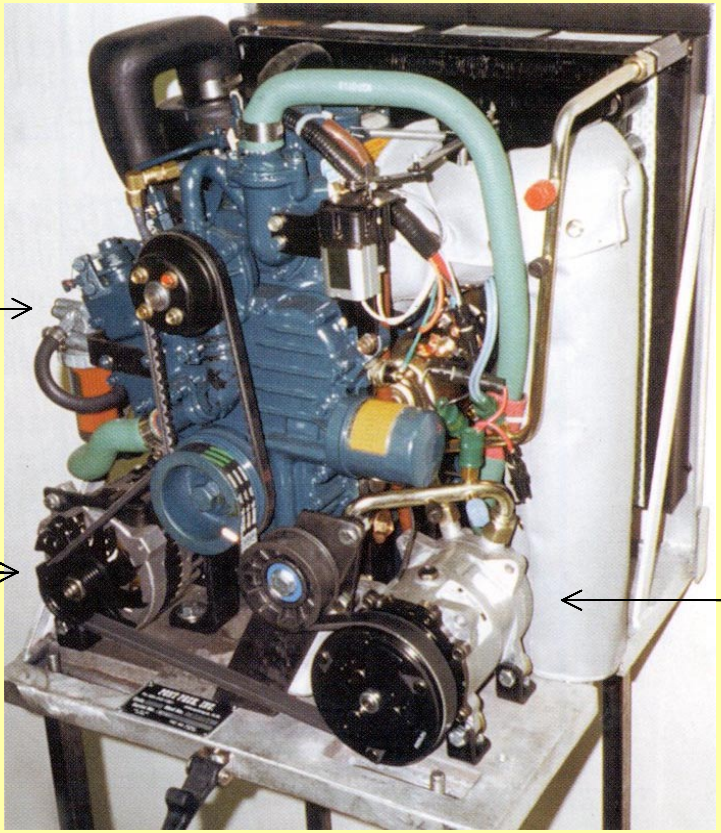
  Oxygen/Carbon: 0.38
- 1,825 Btu/lb LHV (94 Btu/SCF)
- Gas content (vol%):

| | |
|---|---|
| - 1.4 $CH_4$ | - 9.4 $CO_2$ |
| - 5.2 CO | - 37.8 $H_2O$ |
| - 23.4 $H_2$ | - 22.8 $N_2$ |

# Typical, Conventional Equipment

- Prime Power, Mack EM7-300 Engine
  - 300 HP (~224 kW)
  - 46.4% (LHV) (engine/rad.)
  - 1,530 liters
  - ~1,100 kg
  - ~$100/kW
  - Other parameters
- Auxiliary Power Unit, Pony Pack
  - 0.50 to 0.89 kW electric
  - 3.73 kW electric equivalent air conditioning
  - 29.8% (LHV)
  - 8 cu ft (227 liters)
  - 300 lb (136 kg)
  - $5,600 basic, $1,000 to $2,000 installation

# Pony Pack Auxiliary Power Unit



Radiator

Kubota Diesel Engine

Alternator

A/C Compressor

# Comparison

| | Efficiency<br>% LHV | $CO_2$ Emissions<br>kg/kWh |
|---|---|---|
| **Fuel Cell** | 39.6 | .68 |
| **Pony Pack** | 29.8 | .90 |
| **Truck engine at idle** | 11.0 | 2.44 |

# Auxiliary Power Application Conclusions

- SOFC versus idling:
  - Total US, Class 8 fleet fuel savings is ~420 million gallons of diesel annually
  - 4.6 million tons $CO_2$ reduction annually
- SOFC versus conventional auxiliary power unit:
  - ~48 million gallons of diesel saved annually
  - 0.63 million tons $CO_2$ reduction annually
  - Fuel cell unit twice volume & 16% heavier

- Planar SOFC is competitive compared to idling & to conventional aux power unit

# Needed Technology Improvement

## SOFC

- Adapt existing planar SOFCs to transportation environment (robust cells – e.g., via thermal expansion compatibility of cell components)
- Design SOFC stack for quick start
- Conduct improvement program: reduce volume, reduce weight, improve performance, lower cost
- Demonstrate endurance & reliability
- Initiate alternatives: 150°C $\Delta$T cell, 700°C cell

## Fuel Processor

- Design for quick start; examine transient issues
- Examine catalyst issues (deactivation from liquid HC)
- Demonstrate endurance & reliability
- Conduct improvement program: reduce volume, reduce weight, improve performance, lower cost