UTC Power

A United Technologies Company

Fuel Cell Development Status

Michael Short

Systems Engineering Manager

United Technologies Corporation

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Fortune 50 corporation

$52.9B in annual sales in 2009

~60% of Sales are in building technologies

UTC Power

UTC Fire
& Security

Research
Center

Hamilton
Sundstrand

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About Us

- Fuel cell technology leader since 1958
- ~ 550 employees
- 768+ Active U.S. patents, more than 300 additional U.S. patents pending
- Global leader in efficient, reliable, and sustainable fuel cell solutions

Stationary Fuel Cells

Transportation

Space & Defense

PureCell® Model 400 Solution

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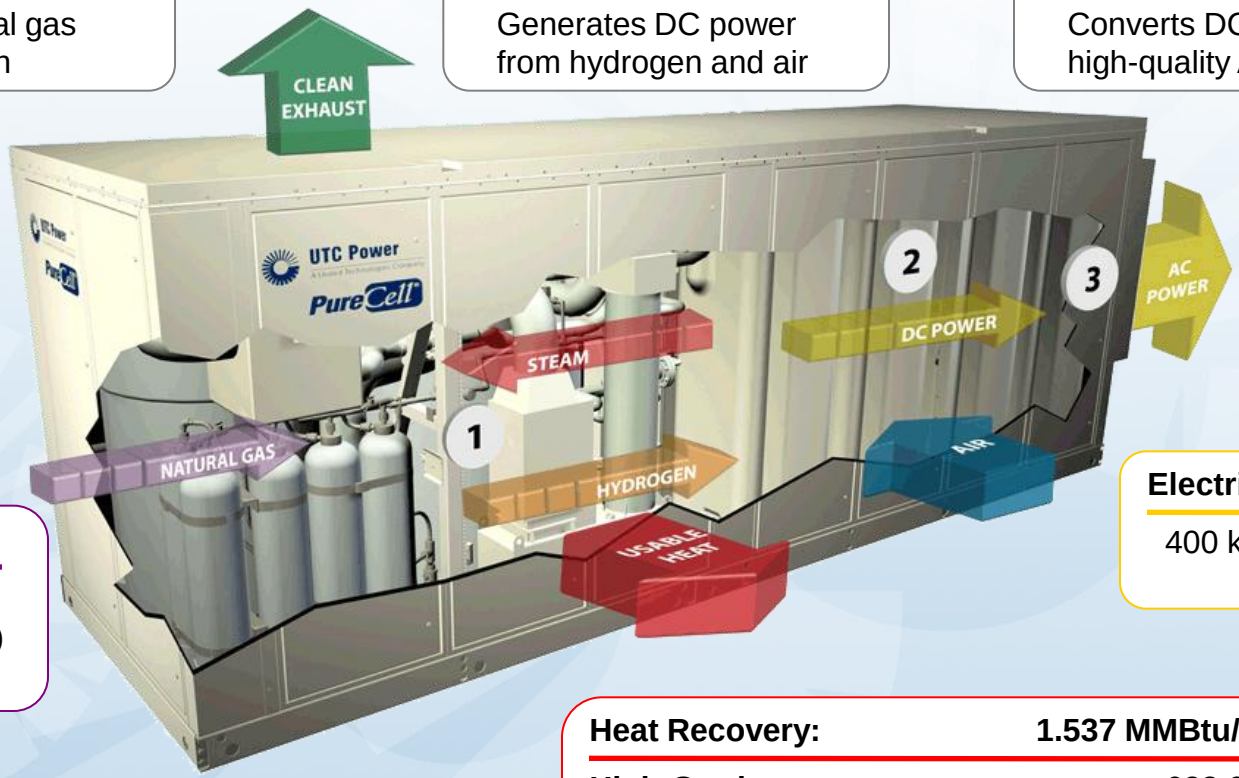
Process Overview

1 Fuel Processor
Converts natural gas fuel to hydrogen

2 Fuel Cell Stack
Generates DC power from hydrogen and air

3 Power Conditioner
Converts DC power to high-quality AC power



Overall System Efficiency Up To 90%

Fuel Input (LHV):
Natural gas
3.2 MMBtu/hr (950 kW)

Electric Output: **42%**
400 kW, 480V, 60 Hz

Heat Recovery:	**1.537 MMBtu/hr (kW)**
High-Grade up to 250°F (120°C)	683,000 (200)
Low-Grade up to 140°F (60°C)	854,000 (250)

All Values are Beginning-of-Life (BOL)

Product Certified To FC-1 & CARB 2007

Environmental Benefits

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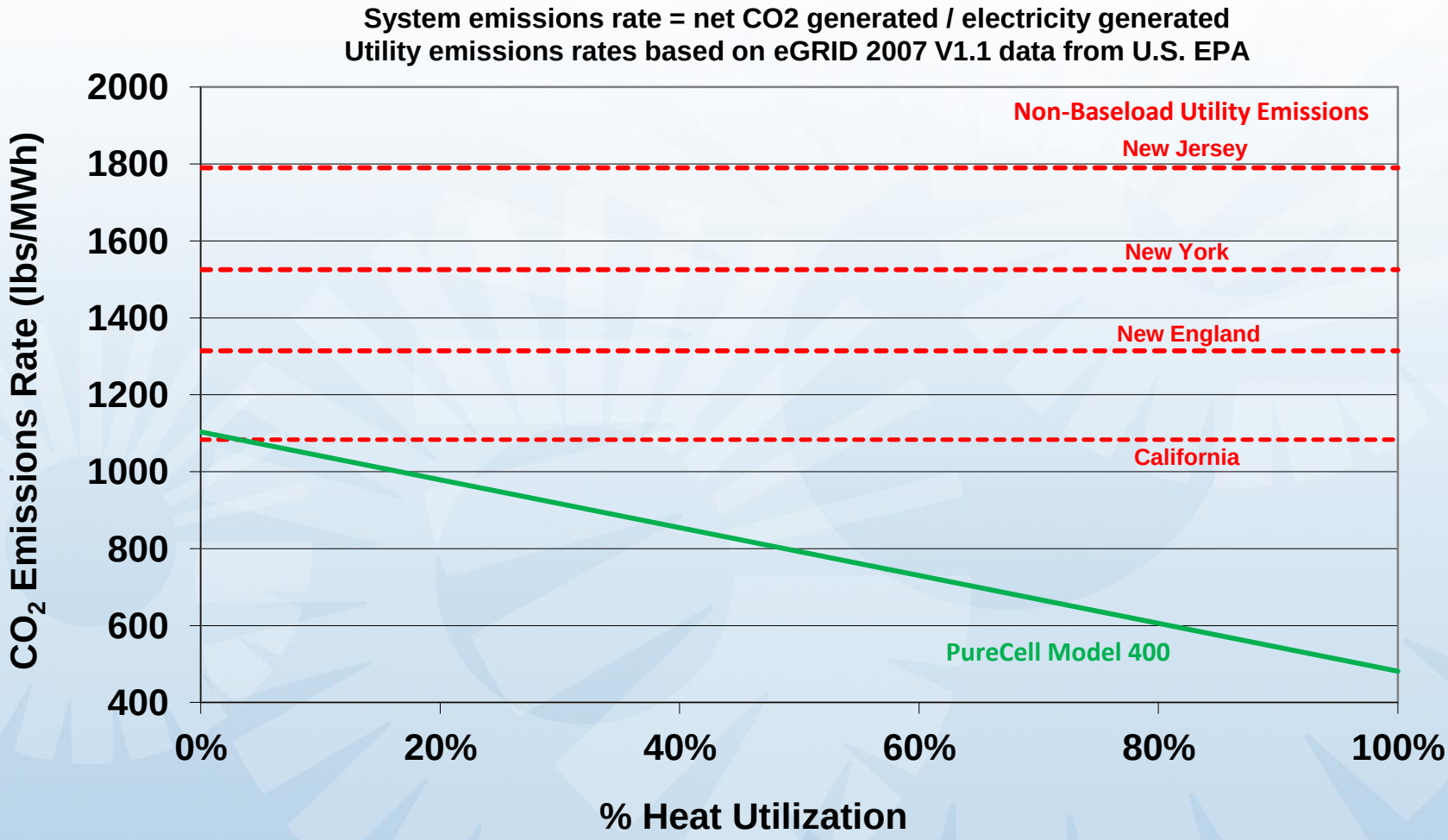
PureCell® Model 400 CO_2 Emissions Rate vs. Heat Utilization



PureCell® Model 400 Manufacturing

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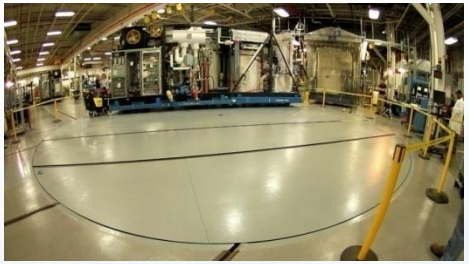
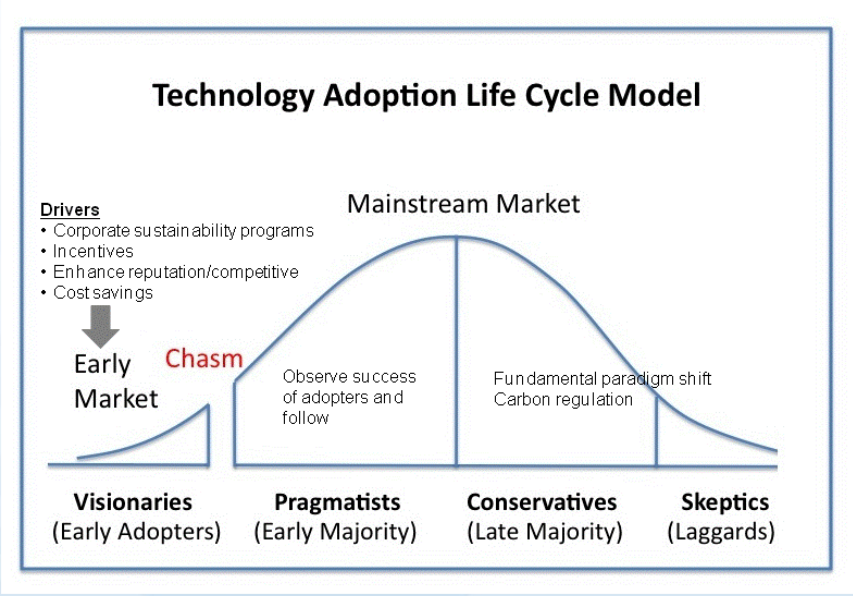
- Manufacturing plant modernization completed
  - Automated cell stack assembly/robotics
  - New cell stack test stands in place
  - Rail/turntable assembly line to rapidly move powerplants – eliminating cranes
  - New final test stands for completed power plant



Key Challenges and Barriers

- Product cost
- Thermal utilization and integration
- Fluctuating incentives
- Other clean energy alternatives
- Sub-metering restrictions
- Existing building retrofit schedules
- Changing economy & operators building philosophy



Transportation Fuel Cells

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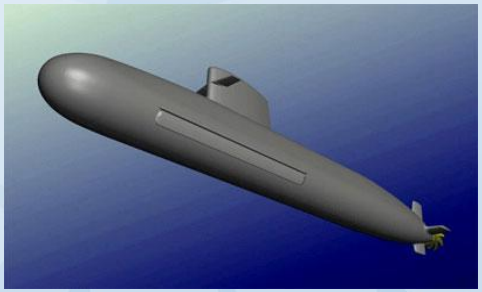

Transportation Fuel Cells

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PureMotion® 120 fuel cell power plant for buses
PEM fuel cell, 120 kW, hydrogen

Automotive fuel cell systems for primary power
PEM fuel cell, 60-80 kW, hydrogen

Automotive fuel cell systems for auxiliary and traction power and technology development
PEM fuel cell, 5 kW, hydrogen

Fuel cell system for the Space Shuttle Orbiter
Alkaline fuel cell, 12 kW, hydrogen

Transit Fuel Cells

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AC TRANSIT · CT TRANSIT · SunLine TRANSIT AGENCY · De Lijn

Original Fleet

PureMotion®120 fuel cell for transit bus applicati…

Fleet of six buses in California, Connecticut and Belgium

Two buses continue to operate in California and Connecticut

PEM Stack durability demonstrated in revenue service

Fleet recorded 471,000 miles, 46,800 hours & 11,300 starts

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015

Current Fleet

Next Generation PureMotion®120 for transit bus application

Sixteen new fuel cell buses in California and Connecticut

Entered revenue service August 2010 – April 2011

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Next Generation Fuel Cell Power System

FTA | United States Department of Transportation Federal Transit Administration

CalStart

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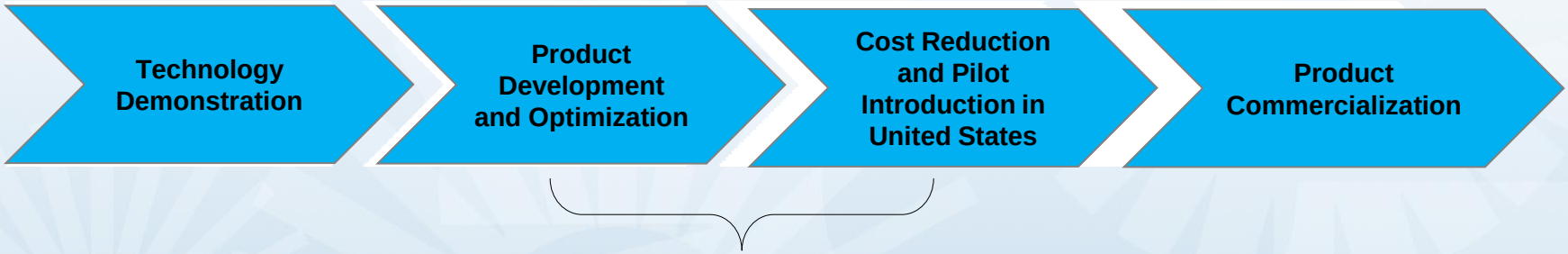

$14.4M Program for advanced fuel cell development

- Continued commercialization
- Reduce product cost
- Reduce size and weight
- Increase durability

Space and Defense Fuel Cells

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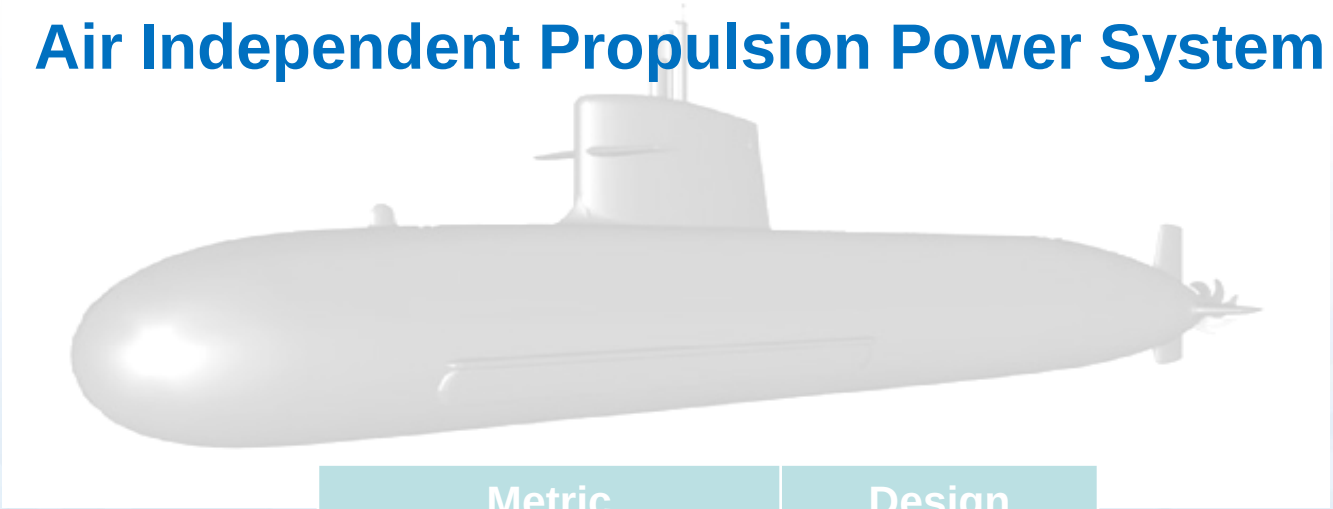
Air Independent Propulsion Power System



Metric	Design Status
Average Net Power	300 kW
Fuel	Bio-ethanol Reformate
Oxidant	Pure Oxygen
Shock & Vibration	US Naval Equivalent
Tilt	Submarine Requirements

Advanced SOFC Systems

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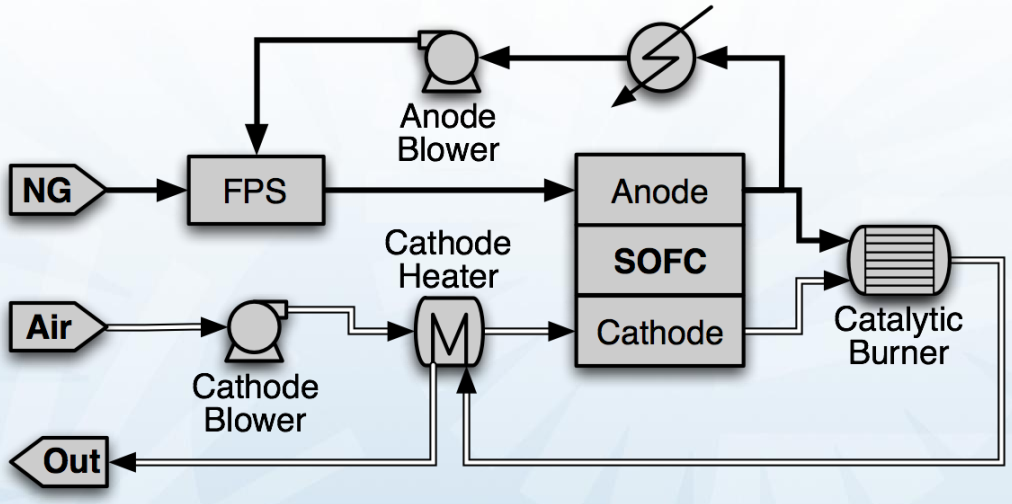
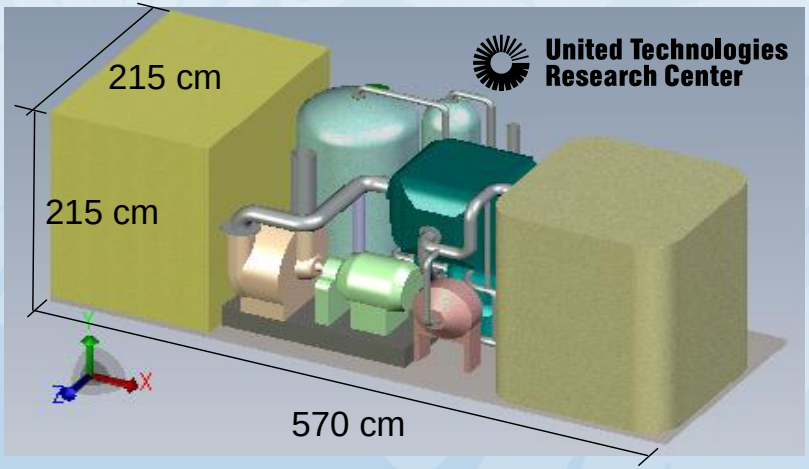
High efficiency (55%) achievable in a simple atmospheric system on NG

- High overall fuel utilization via anode recycling,
- High level of in-stack methane reforming
- Commitment to lower parasitic power loss from balance-of-plant (BOP) components.





Conceptual layout of a net 400 kW SOFC power system

- Levelized cost of electricity, driven by durability, efficiency & equipment cost, is the key figure of merit for commercialization
- **Stack scale up** (>50 kW) and **durability** (>40,000 h) represents the largest technology gap

Advanced SOFC Systems

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TRL-3 in Q4 10

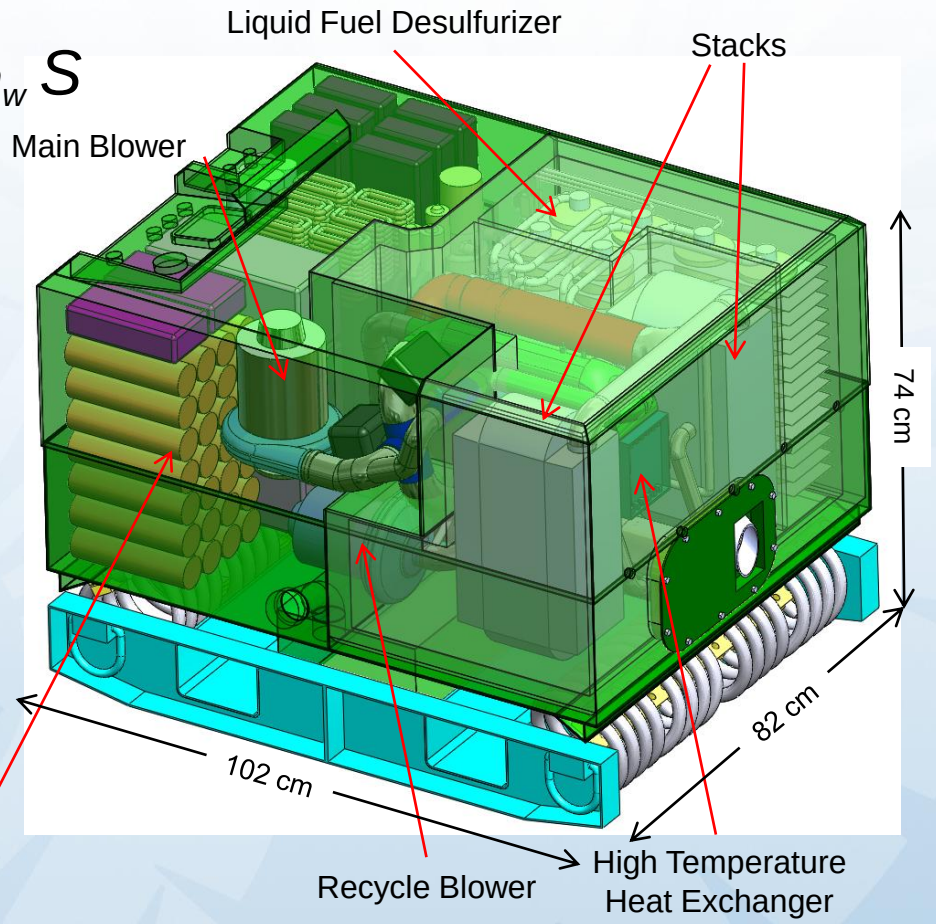
Ground Generator

12 kW on JP-8, JP-5, ULSD with < 400 ppm_w S

Metric	Design Status
Average Net Power (kW)	12
Net Efficiency	35%
Power Density (W/L)	20
Specific Power (W/kg)	40
Start Up Time (min)	< 30 min
Mil-Std Comp.	Yes
Maintenance Int. (hrs)	≥ 150

Ambient Rating Conditions: 4000 ft altitude, 95 ℉

Design Challenges – power density, 30 minute start up on liquid fuels



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Advanced SOFC Systems

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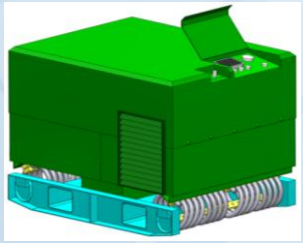
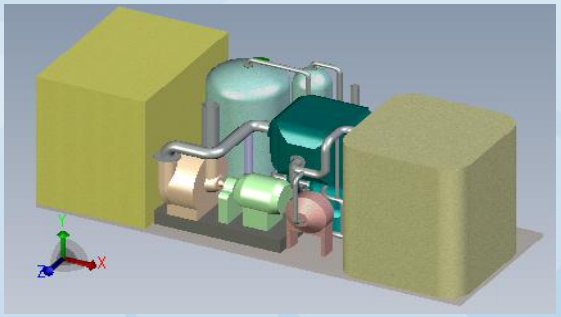
SOFC Markets, Value Proposition & Challenges

	Mobile	Stationary
Applications	• UAV Primary Propulsion • Vehicle/Aircraft APU • Ground Generator • UUV Power & Propulsion	• CHP • Grid-Scale Electricity
Value Prop	•*Efficient (& quiet) electric power from hydrocarbon fuels*	
Development Challenges	• Size • Weight • Durability (Ruggedness)	• Cost • Life



Different Scales



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THANK YOU !

www.utcpower.com

R041310

How A Fuel Cell Works

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1

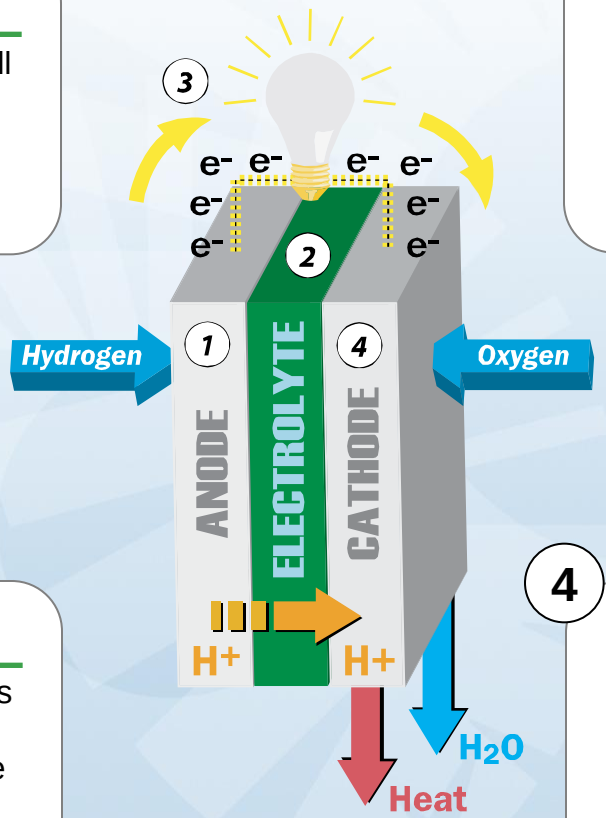
Anode

As hydrogen flows into the fuel cell anode, a catalyst layer on the anode helps to separate the hydrogen atoms into protons (hydrogen ions) and electrons.

3

External Circuit

The electrons cannot pass through this electrolyte and, therefore, must flow through an external circuit in the form of electric current. This current can power an electric load.



2

Electrolyte

The electrolyte in the center allows only the protons to pass through the electrolyte to the cathode side of the fuel cell.

4

Cathode

As oxygen flows into the fuel cell cathode, another catalyst layer helps the oxygen, protons, and electrons combine to produce pure water and heat.

How A Fuel Cell Works

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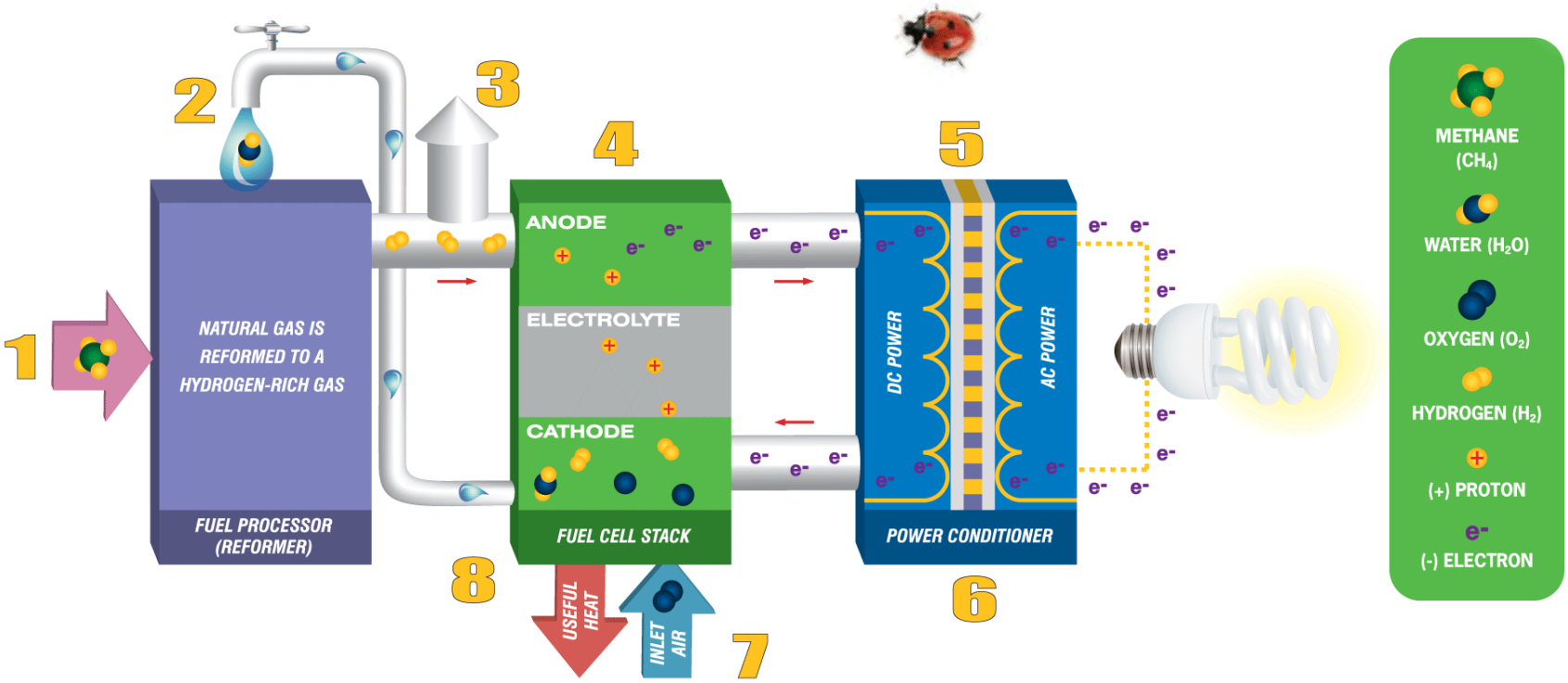
It's a Wrap! – Connecticut Science Center



1. Natural Gas (largely Methane (CH_4)) is supplied to the Fuel Cell.
2. Steam (H_2O), as a by-product of the system, is used to reform the Natural Gas into Hydrogen-rich Gas (H_2 Reformate).
3. Clean exhaust is vented. The PureCell® system avoids 273 metric tons of CO_2 emissions each year as compared to conventional power generation.
4. A catalytic reaction converts the Hydrogen (H_2) into Protons and Electrons. The positively charged Protons pass through the Fuel Cell Electrolyte.
5. The negatively charged Electrons flow through an external circuit to produce Electricity.
6. DC Power is conditioned to provide high-quality Alternating Current (AC) output power.
7. The Electrons and Protons recombine with Oxygen (O_2) from the air to create Water (H_2O), which is put back into the system as steam.
8. The remaining by-product is useful Heat.

PureCell® Model 400 Solution

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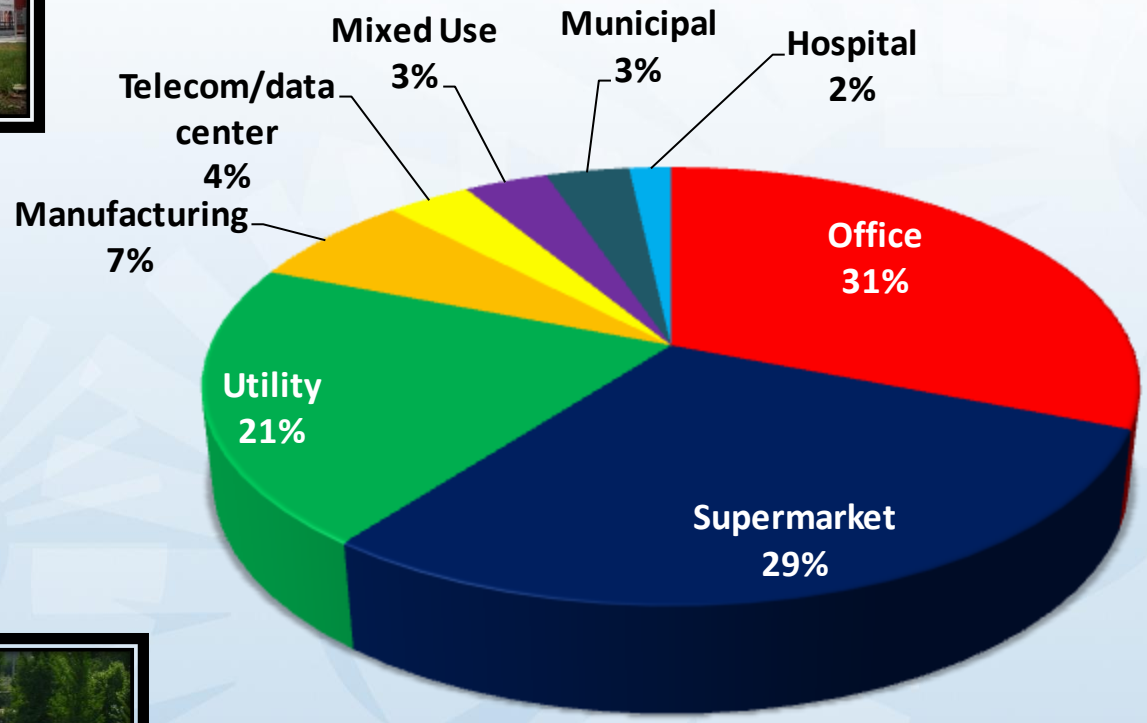
Market Segments Addressed



Transit Fuel Cells

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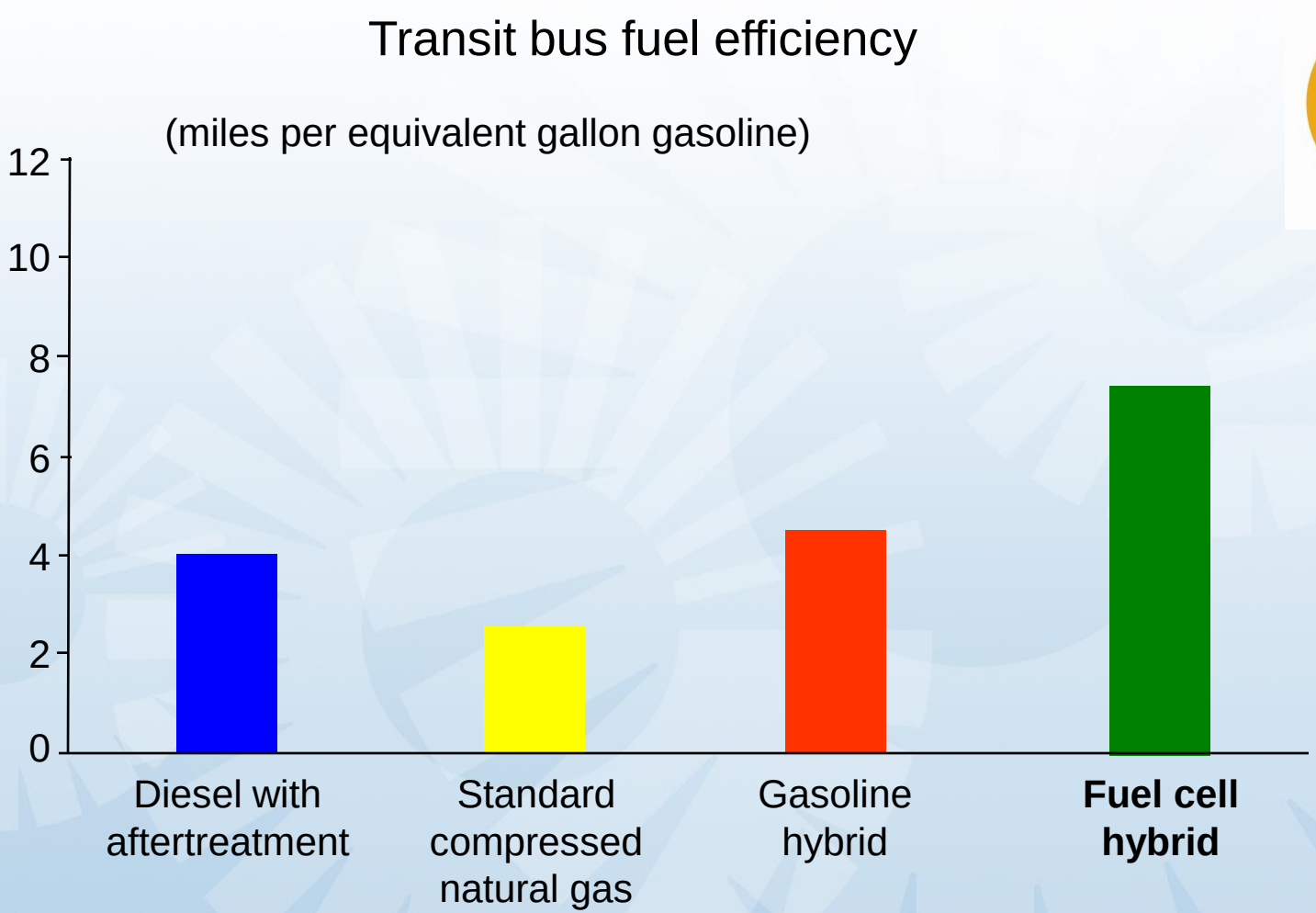
energy productivity



Source: AC Transit ; http://www.actransit.org/environment/hyroad_environmental.wu