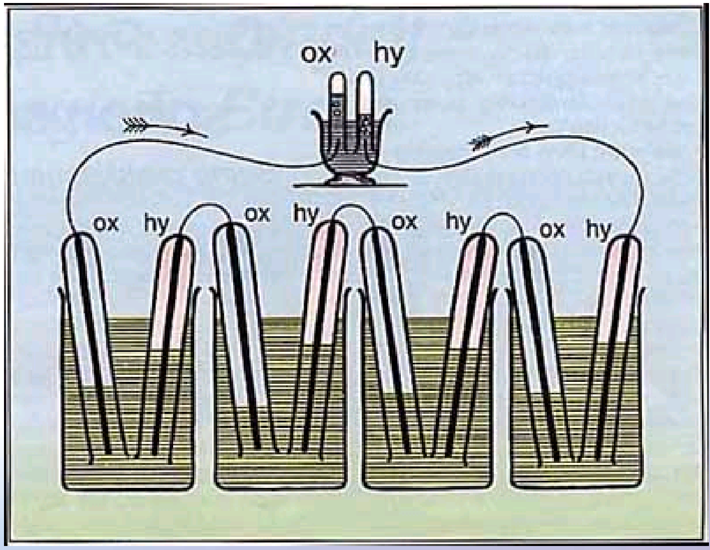
FMI ENERGY CONFERENCE

Orlando

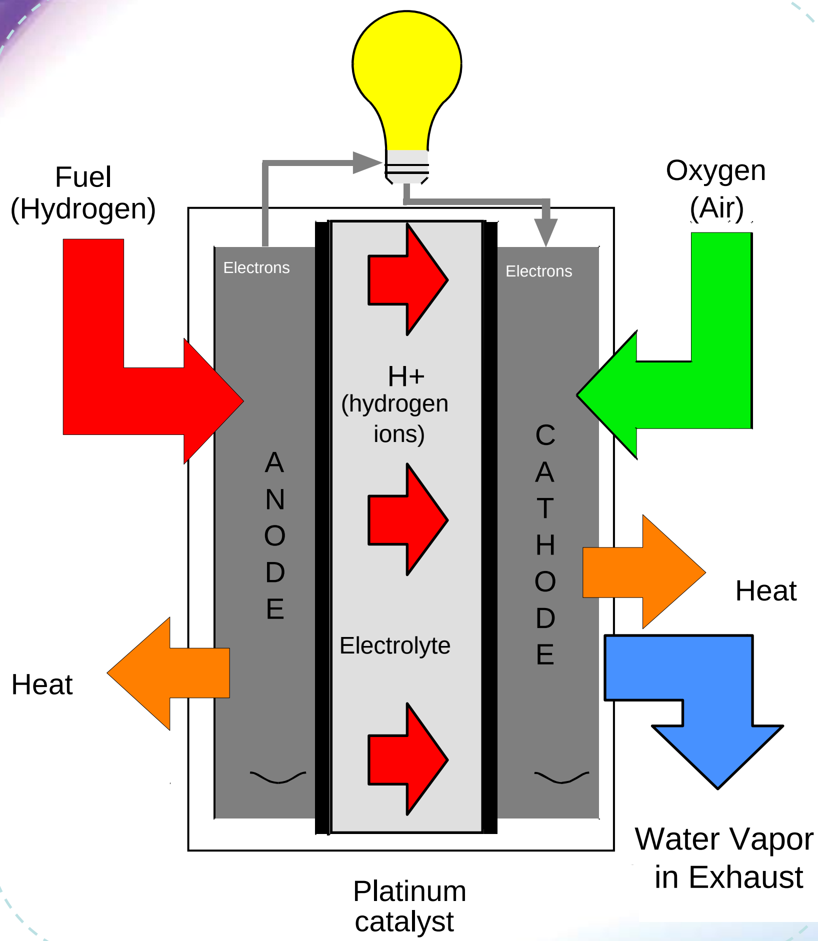
September 2008

FUEL CELL ORIGINS

- **Sir William Grove** invented the fuel cell in 1839
- Demonstrated that reaction was reversible
- "Fuel cell" term introduced by Ludwig Mond and Charles Langer in 1889
  - Attempted to develop coal-gas/air fuel cells



HOW A FUEL CELL WORKS



1. **Hydrogen flows into the fuel cell anode, where it is separated into protons (hydrogen ions) and electrons**
2. **Protons pass through the electrolyte to the cathode**
3. **Electrons flow through an external circuit in the form of electric current**
4. **Oxygen flows into the fuel cell cathode, where it helps protons and electrons combine to produce pure water and heat**

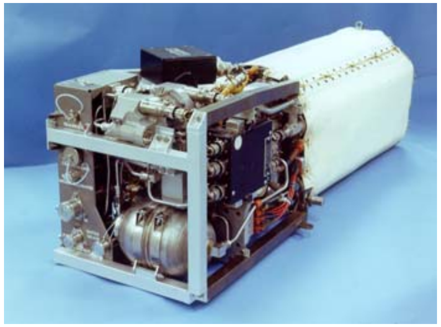
FUEL CELL TECHNOLOGIES

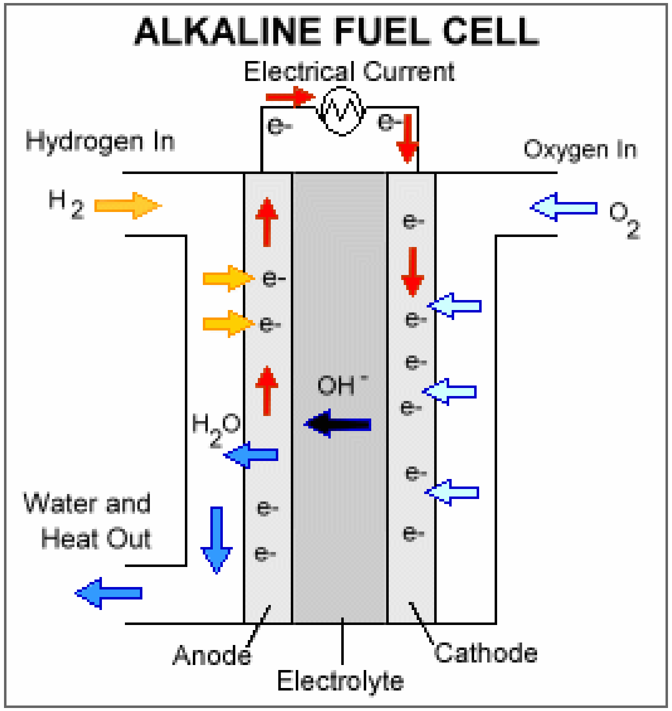
	Fuel Cell Type	Applications	Operating Temperature ºF	Comments
	Alkaline	Space	176 - 212	Needs pure Hydrogen & Oxygen
	Phosphoric Acid	Stationary	392 - 428	Long life High Efficiency Good co-generation
	Proton Exchange Membrane	Stationary Transportation	176 - 212	Short start time Easily manufactured Size / scalability
	Molten Carbonate	Stationary	1,100 – 1,200	Short Life High efficiency Good co-generation
	Solid Oxide	Stationary	1,200 – 1,800	High efficiency Exotic materials

ALKALINE FUEL CELLS

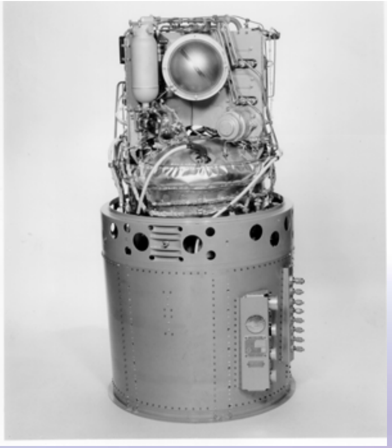
Space Shuttle

12 kW Shuttle fuel cell





- Electrolyte: Potassium Hydroxide (KOH)
- Strengths
  - Fast reaction kinetics
  - Good power density
  - Low temperature operation
- Weaknesses
  - Not tolerant to CO_2
  - Forms carbonates in electrolyte that precipitate
- Primary Application(s):
  - Transportation applications with pure H_2 and O_2



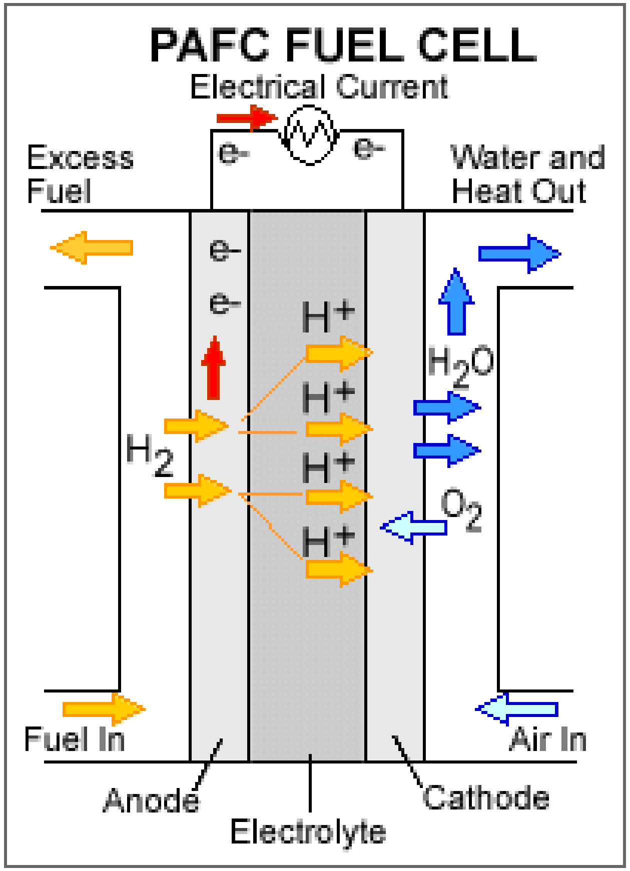
1.2 kW Apollo Fuel Cell

PHOSPHORIC ACID FUEL CELLS - 1

Supermarket

Glastonbury, CT

200 kW fuel cell



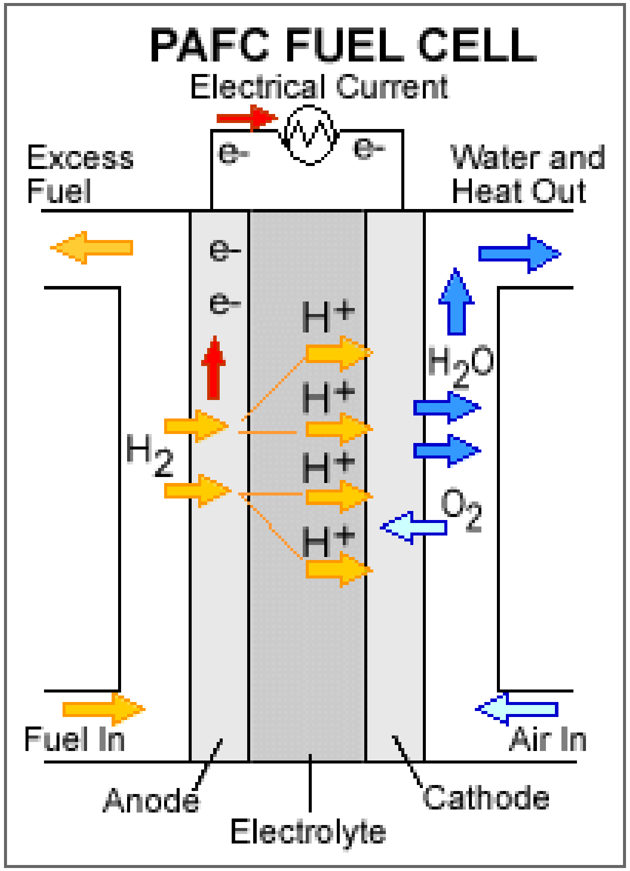
- Electrolyte: Liquid Phosphoric Acid
- Strengths
  - Long-life
  - High cogeneration efficiency
  - Performs well with reformate fuel containing CO
- Weaknesses
  - Power Density / Footprint
- Primary Application(s):
  - Commercial Building cogeneration systems
  - Wastewater Treatment Plants using Anaeobic Digester Gas

PHOSPHORIC ACID FUEL CELLS - 2

1.4 MW fuel cell system

Verizon Call Center, NY

400 kW fuel cell



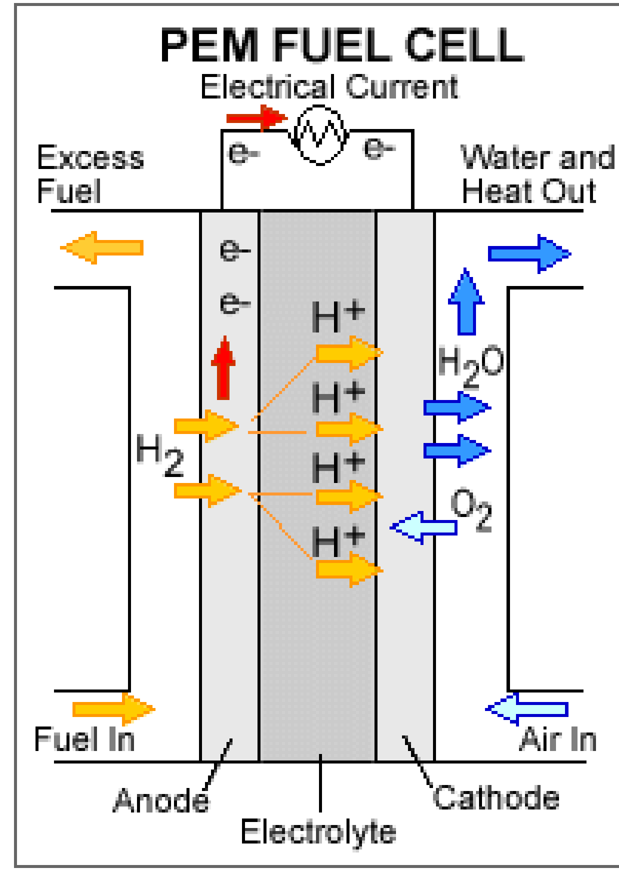
- Electrolyte: Liquid Phosphoric Acid
- Strengths
  - Long-life
  - High cogeneration efficiency
  - Performs well with reformate fuel containing CO
- Weaknesses
  - Power Density / Footprint
- Primary Application(s):
  - Commercial Building cogeneration systems

PROTON EXCHANGE MEMBRANE FUEL CELLS

Fuel Cell Bus

AC Transit, CA

Bus Fuel Cell

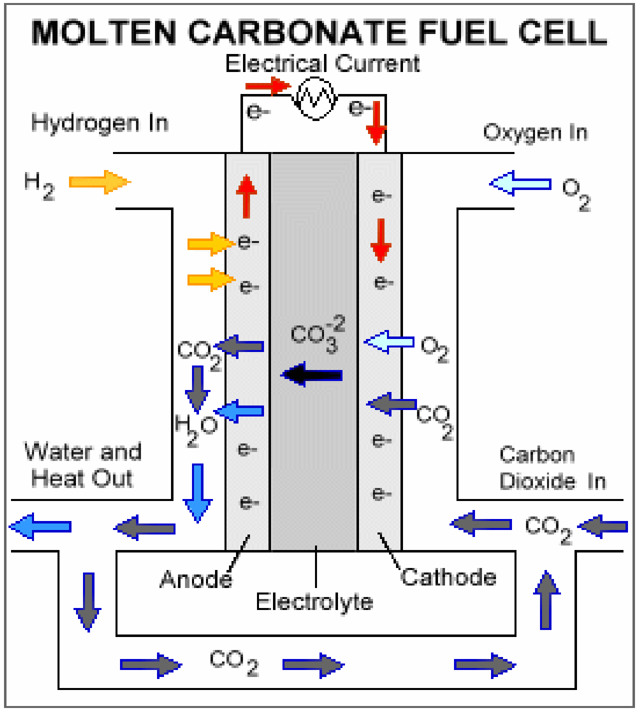


- Electrolyte: thin solid polymer membrane
- Strengths
  - Excellent reaction kinetics
  - Good power density
  - Fast startups (seconds)
- Weaknesses
  - Poor CO tolerance
  - Needs relatively pure fuel
  - Durability
- Primary Application(s):
  - Car, Bus, Tow/Work vehicle applications with H_2 and air
  - Stationary applications (as battery-replacement)

MOLTEN CARBONATE FUEL CELLS

<u>Wastewater Treatment Plant</u>

Palmdale, CA

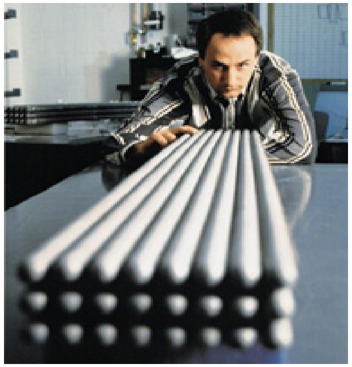


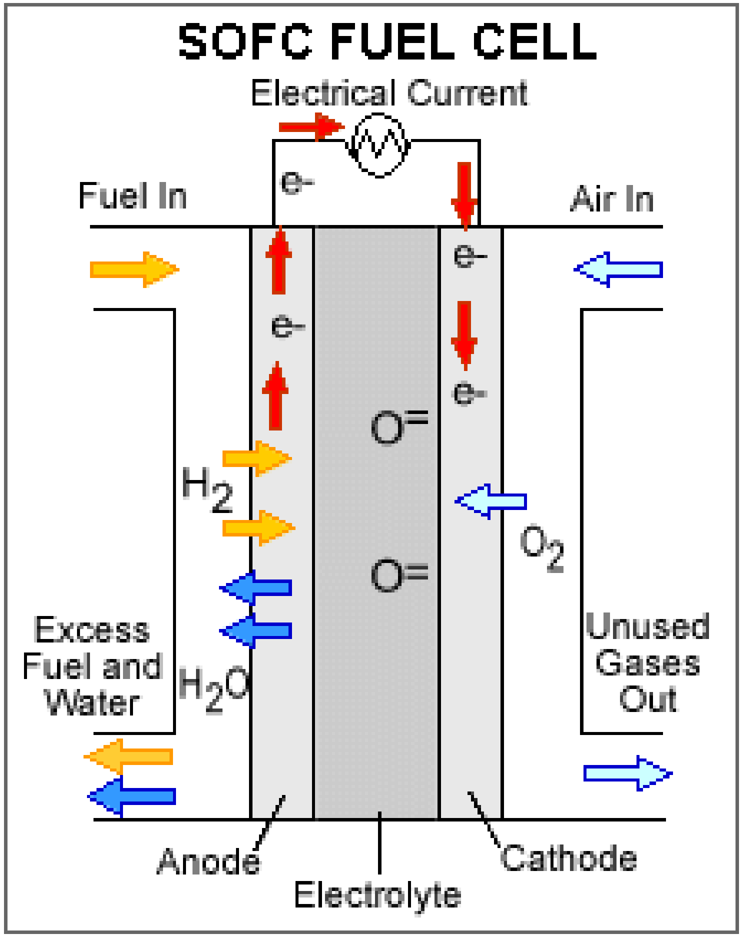
- Electrolyte: Molten salt in porous ceramic (LiAlO2)
- Strengths:
  - High Electrical Efficiency
  - Cogeneration
  - Simple system
- Weaknesses
  - Durability
  - Low power density
  - Slow start
- Primary Application(s):
  - Commercial Building cogeneration systems
  - Wastewater Treatment Plants using Anaerobic Digester Gas (ADG)

SOLID OXIDE FUEL CELLS

250 kW CHP System
Canada

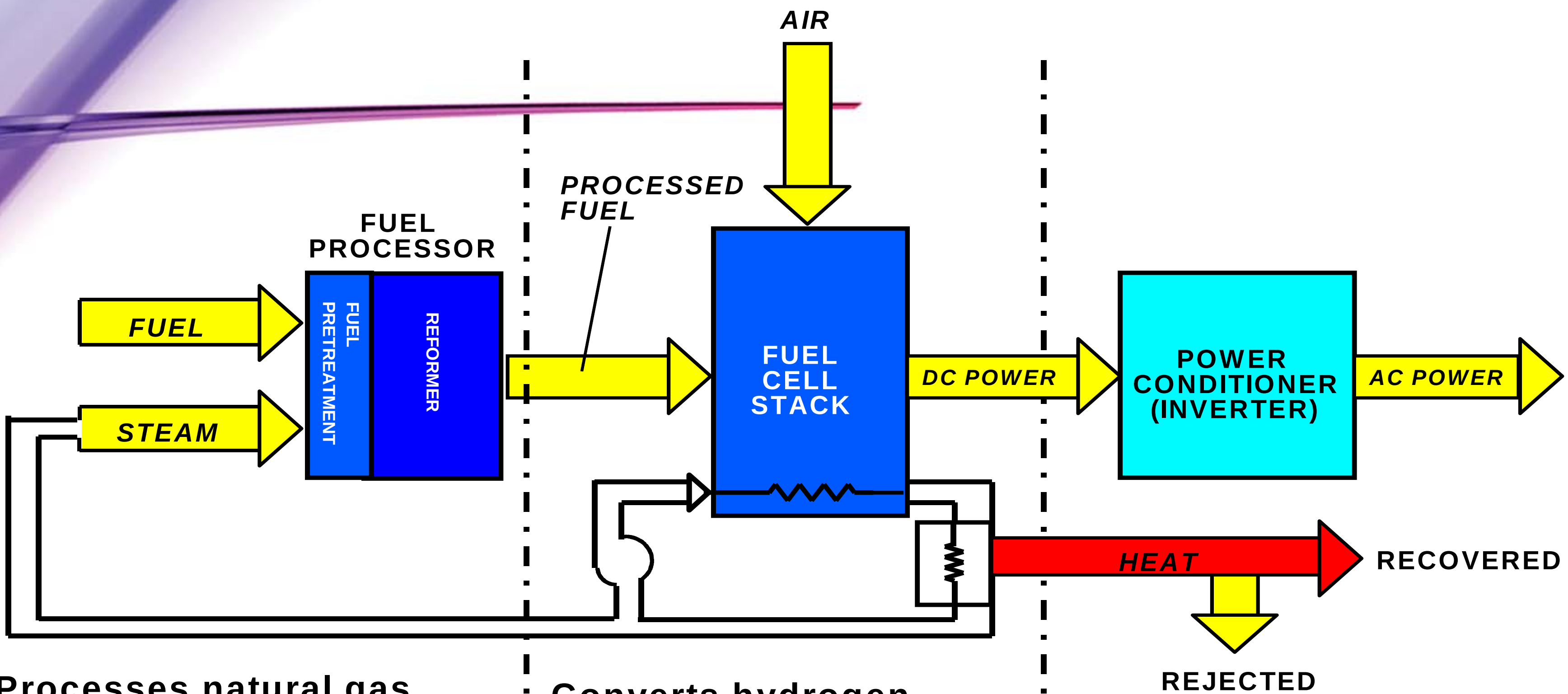
SOFC Cells
Tubular design





- Electrolyte: porous, solid ceramic compound
- Strengths
  - Excellent power density
  - Very simple system
  - Opportunity for hybrid power systems with turbines
- Weaknesses
  - Durability
  - Scaleable to large size uncertain
- Primary Application(s):
  - Stationary applications with natural gas and air
  - Still in demonstration stage

FUEL CELL SYSTEM



Processes natural gas fuel for fuel cell use

$CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$

Converts hydrogen and air into DC power

$H_2 \rightarrow 2H^+ + 2e^-$

$1/2\ O_2 + 2H^+ + 2e^- \rightarrow H_2O$

Converts DC power to usable AC power

PPT-01170
010702

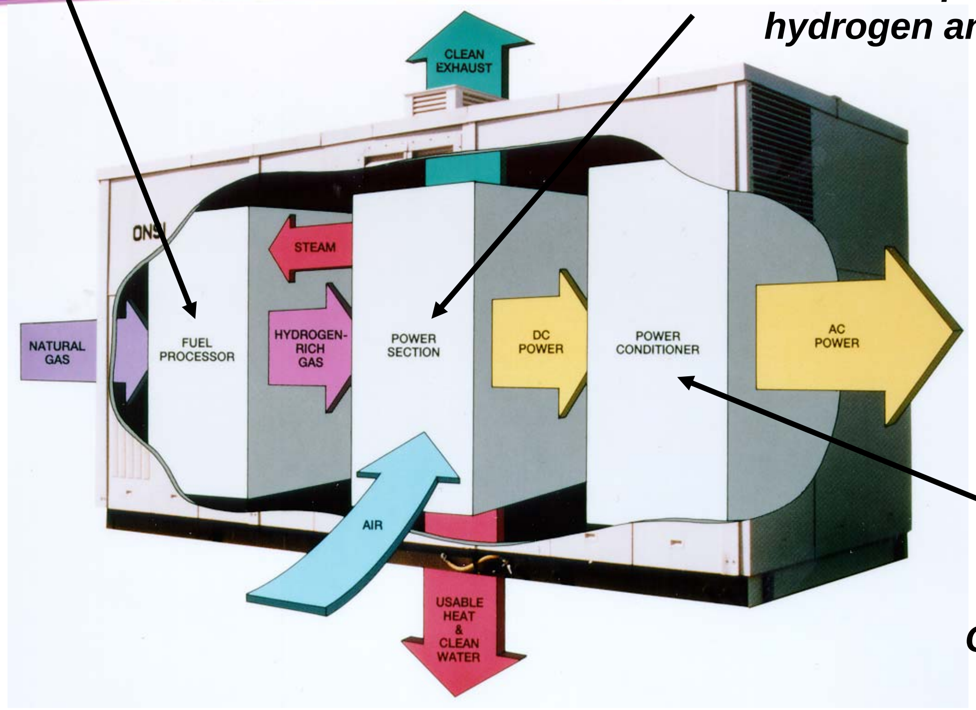
Note: Fuel cell system with separate catalytic steam reformer example shown

FUEL CELL SYSTEM

<u>Fuel Processor</u>
Converts natural gas fuel to hydrogen

<u>Fuel Cell Stack</u>
Generates DC power from hydrogen and air

Fuel Input:
- **Natural gas**
  - **3.79 MMBTU/hr**



Electric Output:
- **400 kW, 480V, 60 Hz**
- **400 kW, 400V, 50 Hz**

<u>Power Conditioner</u>
Converts DC power to high quality AC power

Internal heat exchanger provides either:
- **1.71 MMBtu/hr @ 140°F**

<u>OR</u>

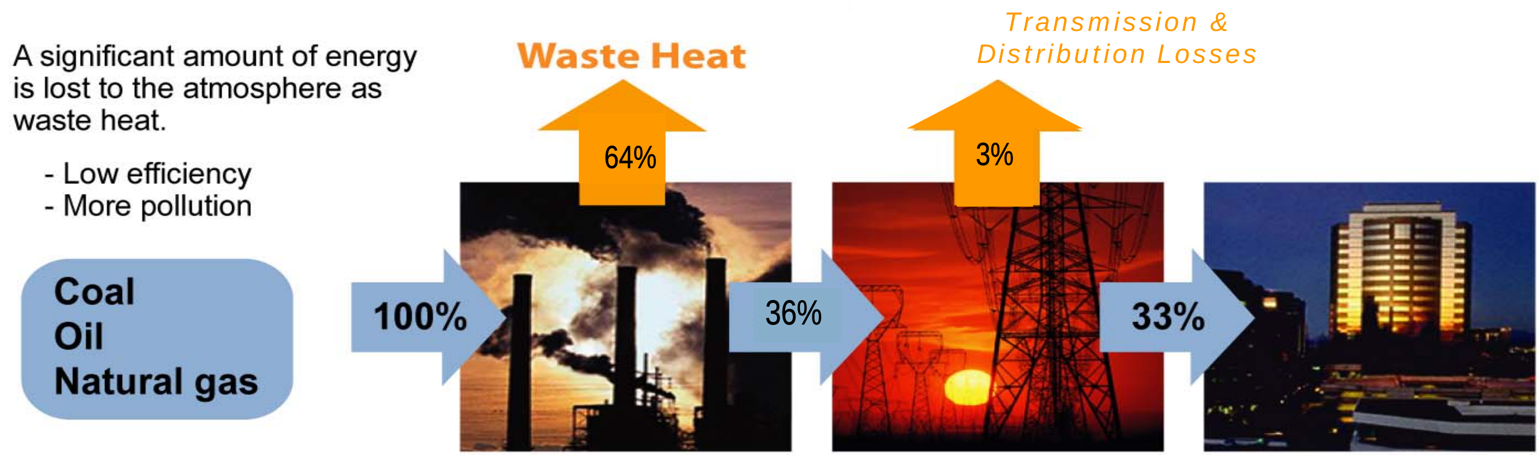
- **0.79 MMBtu/hr @ 250°F & 0.92 MMBTU/hr @ 140°F**

**Nominal values given*

Note: Phosphoric Acid Fuel Cell example shown

FUEL CELL ADVANTAGE

Traditional Central Power Plant



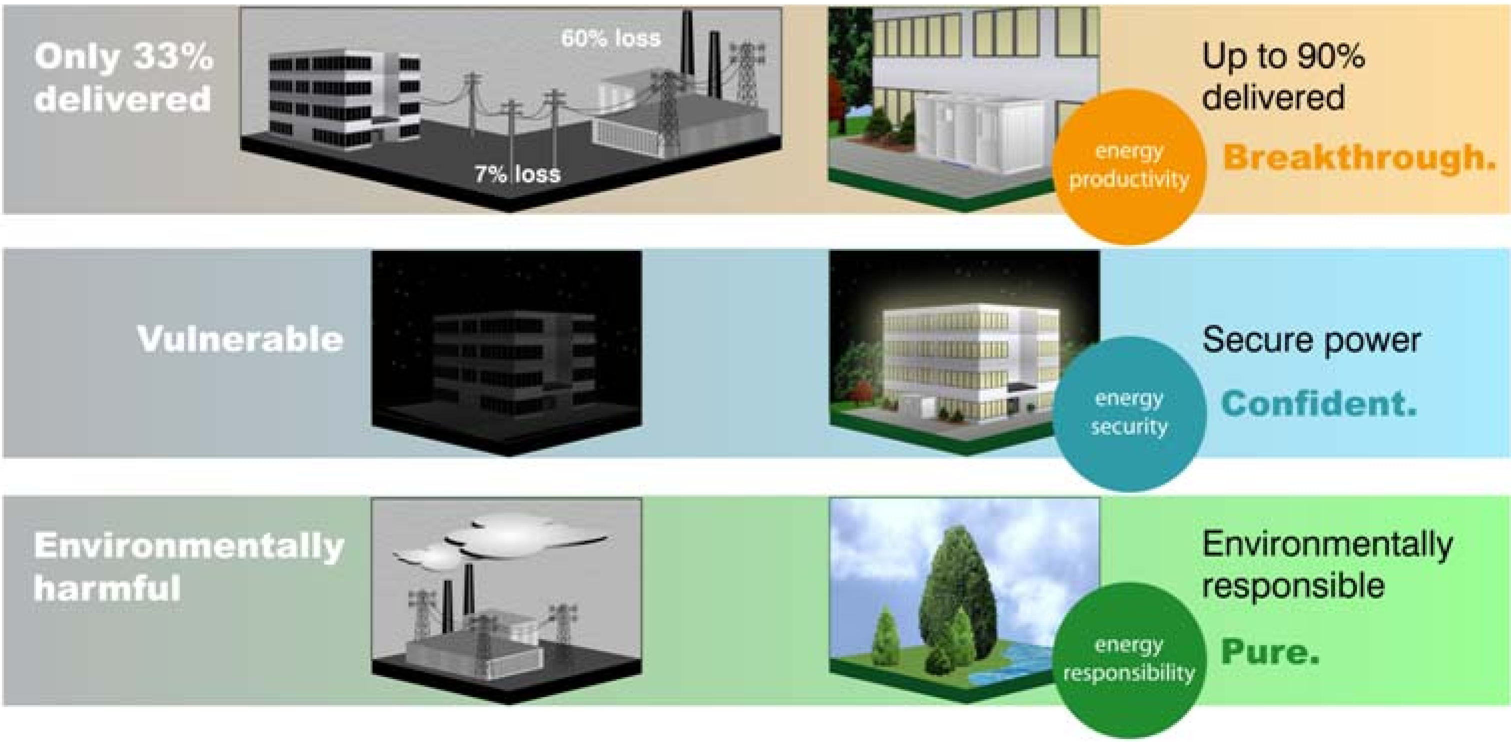
Source: Adapted from U.S. Combined Heat and Power Association.

Fuel Cell Cogeneration Solution

Source: Adapted from U.S. Combined Heat and Power Association.

Fuel Cell Opportunities Drivers

Energy Productivity, Security, Responsibility



Fuel Cell Opportunities

Energy Productivity, Security, Responsibility

- *Clean Energy Benefits*
  - Clean Energy Credits
  - Renewable Energy Credits
  - Carbon Trading
  - Water Credit
  - NOx’s Reduction Trading
  - SOx’s Reduction Trading
  - Insurance Reduction
  - Corporate Mission Compliance
  - Sustainable Futures
  - LEED Points

Fuel Cell Opportunities

Energy Productivity, Security, Responsibility

- *Incentives*
  - Federal Tax Rebates
    - Up to $1000/Kw
  - Demand Response Capabilities
  - State & Local Rebates
    - Up to $4700/KW
  - Low Fluctuation / Fixed or Stable Utility Cost
    - Multiple Year Gas Contracts
    - Thermal Utilization
  - Reliable Back Up Power
    - Vital Loads or Perishable Loads 24/7
  - Emerging Credit Trading Market
    - Installed base future revenue day one

Fuel Cell Opportunities

Energy Productivity, Security, Responsibility

- *System & Integration Advancements*
  - Reduced First Cost With Large Reduction In Energy Usage
    - Refrigeration rack condensing
      - No air cooled condensers
      - No copper to the roof
      - Drastic refrigerant charge reduction
      - Stable condensing at reduced operating cost & maintenance cost
      - Air cooled chiller back up for redundancy
    - HVAC
      - Less Refrigerant charge
      - Less copper & compressors

Fuel Cell Opportunities

Energy Productivity, Security, Responsibility

- *System & Integration Advancements*
  - Fuel Cell Electrical Advantages
    - Stable utility cost (Long term Gas contracts)
    - 24/7 base load with back up
    - Clean sign wave for vital loads
    - Power factor correction capability real time
    - Construction Power* - Heating*
  - Reduced Ownership Cost
    - Capital Lease ($0 out of pocket with capital expenditure tax breaks)
    - Equipment Lease ($0 out of pocket with operational tax breaks)
    - Lease buy out options for tax and incentive advantages

Fuel Cell Opportunities

Energy Productivity, Security, Responsibility

- *Emergency Systems Back Up Power*
  - Elevators
  - Escalators
  - Refrigeration Systems
  - Evacuation
  - P.O.S.
  - Lights
  - Vacuum System

Energy Responsibility

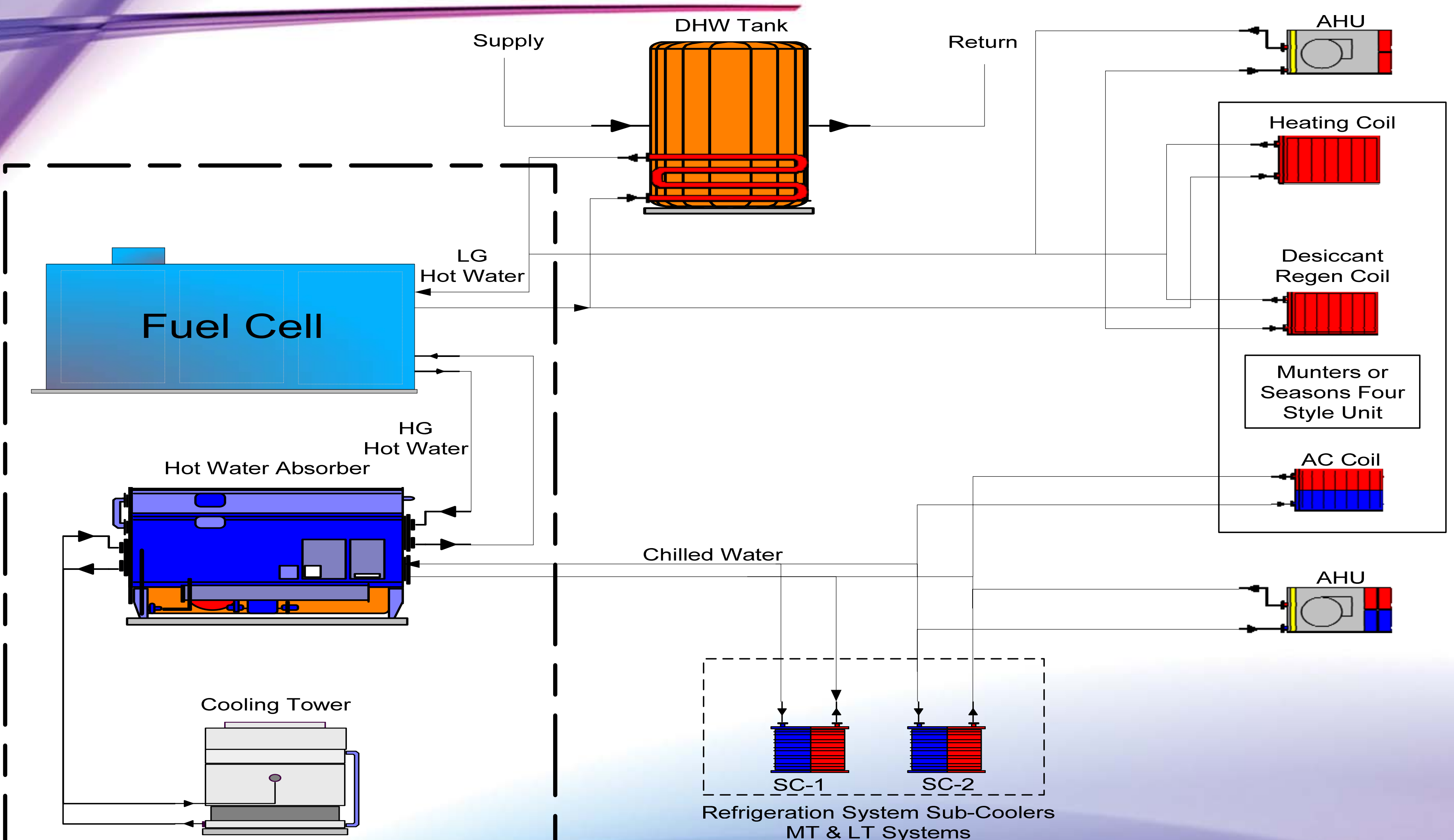
Energy Productivity, Security, Responsibility

Water Conservation - simplifies

- No water permits
- No drainage issues
- Minimizes installation complexity

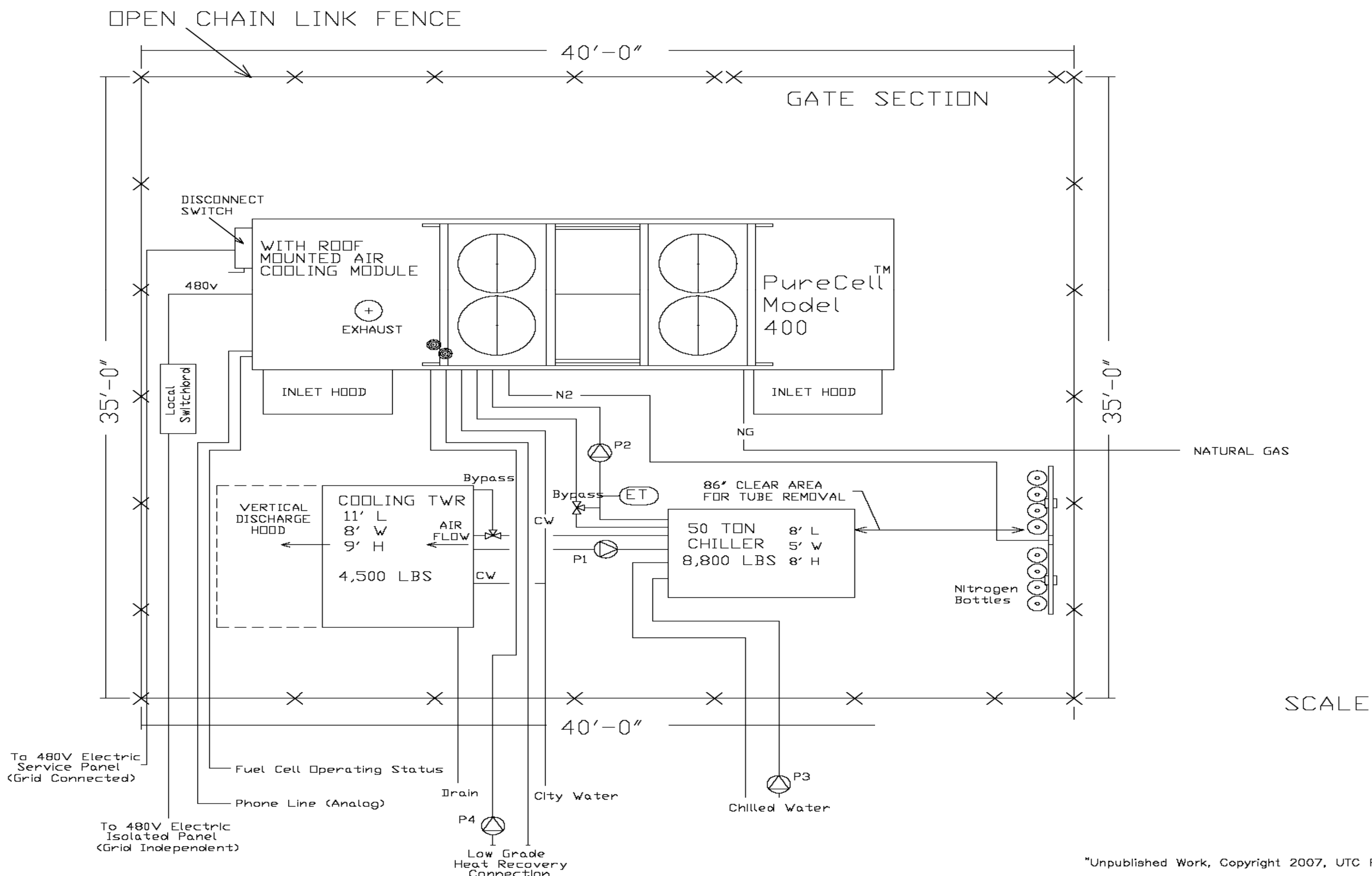
Supermarket Installation Thermal Utilization

Energy Productivity, Security, Responsibility



Proposed Pad Layout

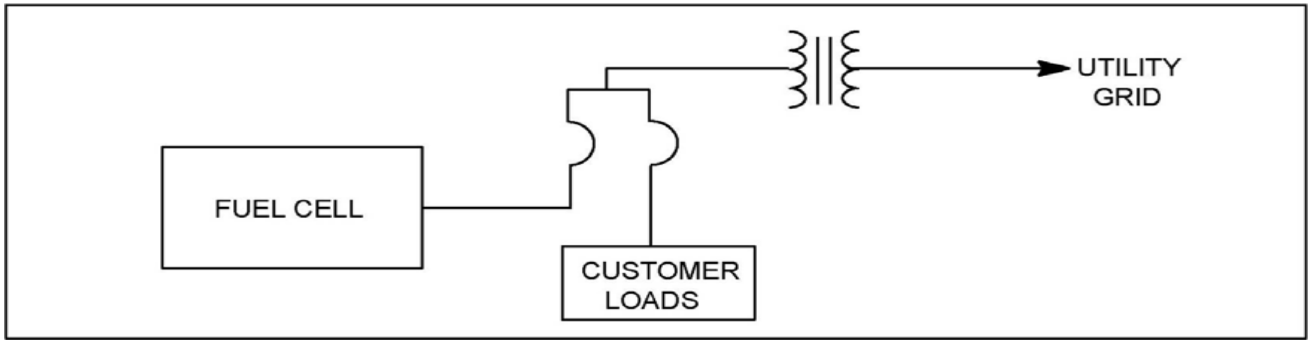
Energy Productivity, Security, Responsibility



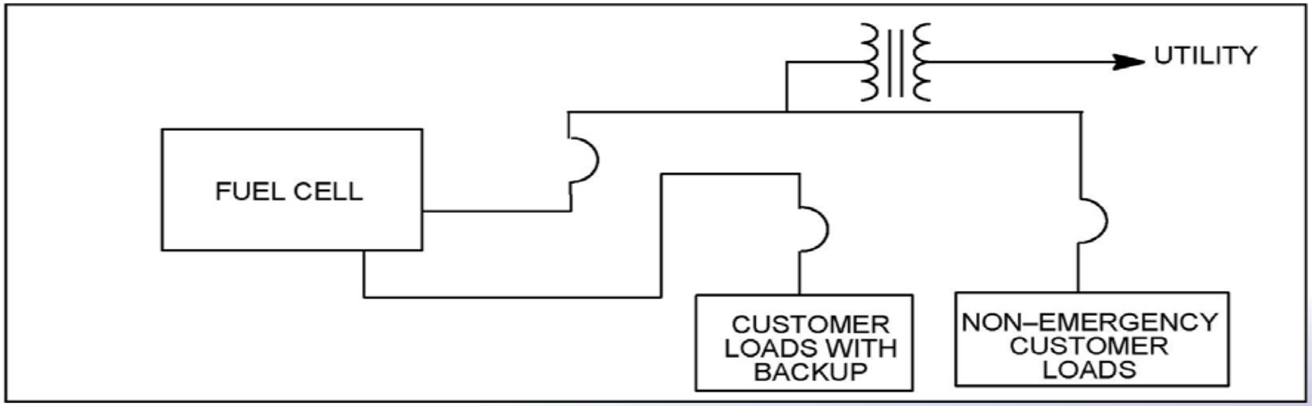
Electrical Operating Modes

Energy Productivity, Security, Responsibility

Grid-Connected



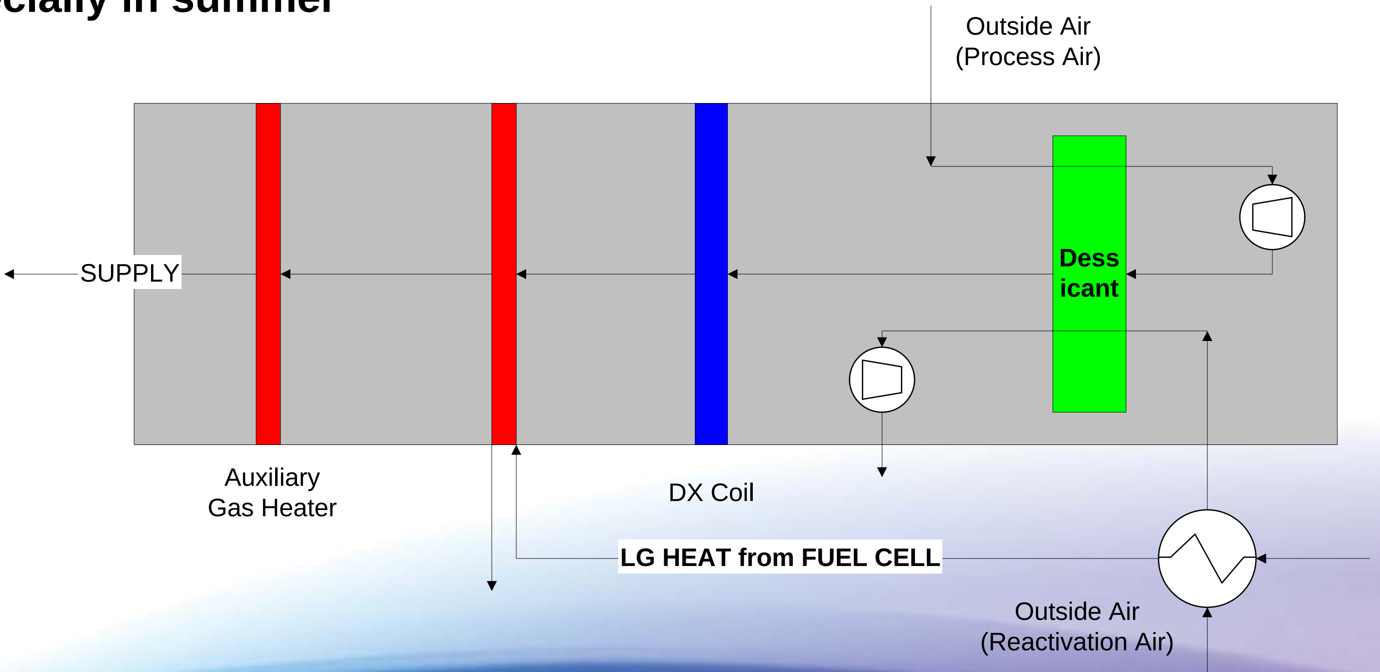
Grid-Connected / Grid-Independent



SUPERMARKET APPLICATION

DEHUMIDIFICATION

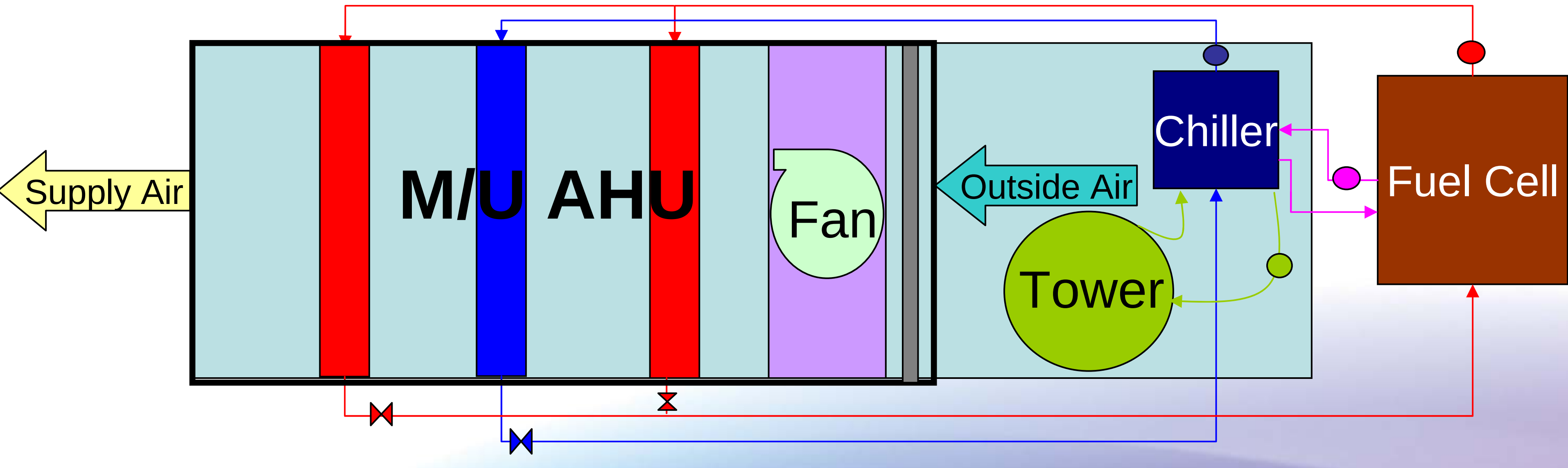
- **Custom design using water coils to heat the reactivation air and provide space heating**
- **Desiccant based dehumidification**
  - **Make-up air handling units only**
- **Benefits**
  - **Energy savings due to fuel cell heat usage especially in summer**



SUPERMARKET APPLICATION

DEHUMIDIFICATION

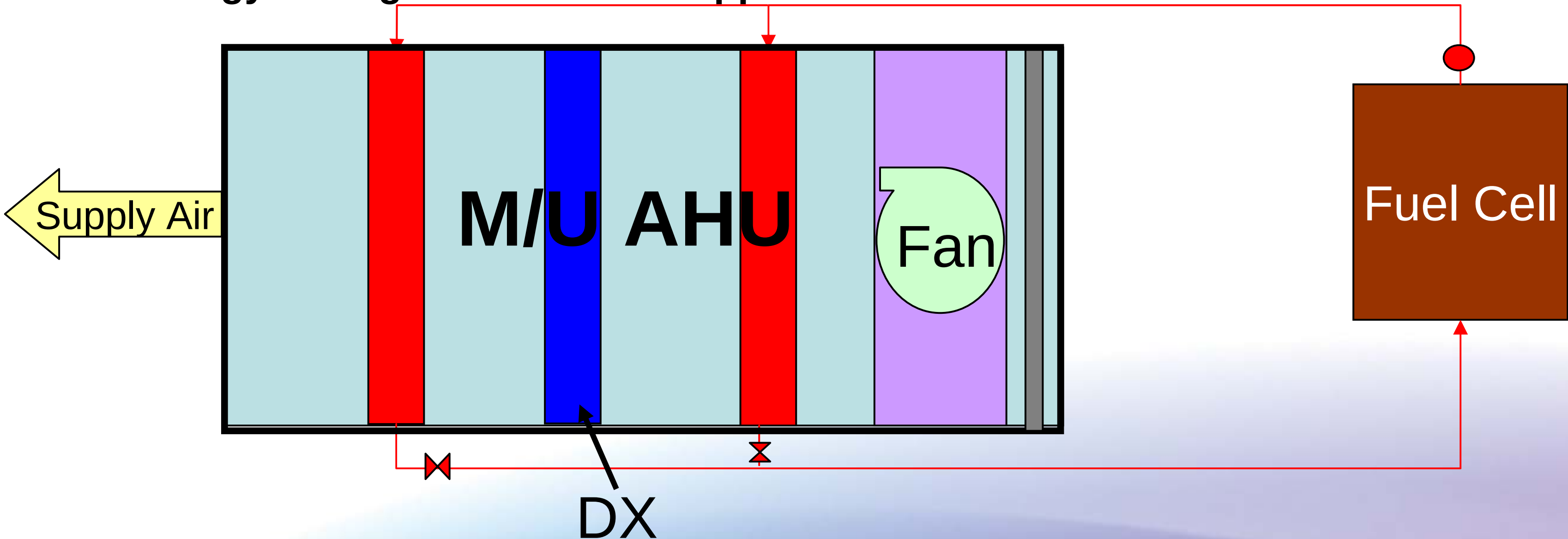
- **Fuel cell with absorption chiller**
- **Custom design using chill water coils and hot water coils to condition air and dehumidify**
- **CCHP RTU**
  - **Reheat based dehumidification**
  - **Make-up air handling units or Standard**
- **Benefits**
  - **Energy savings / Small Store Applications / Retrofit able / Scaleable**



SUPERMARKET APPLICATION

DEHUMIDIFICATION

- Fuel cell with no absorption chiller
- Standard design using DX coils and hot water coils to condition air and dehumidify
- CCHP RTU
  - Reheat based dehumidification
  - Make-up air handling units or Standard
- Benefits
  - Energy savings / Small Store Applications / Retrofit able / Scaleable



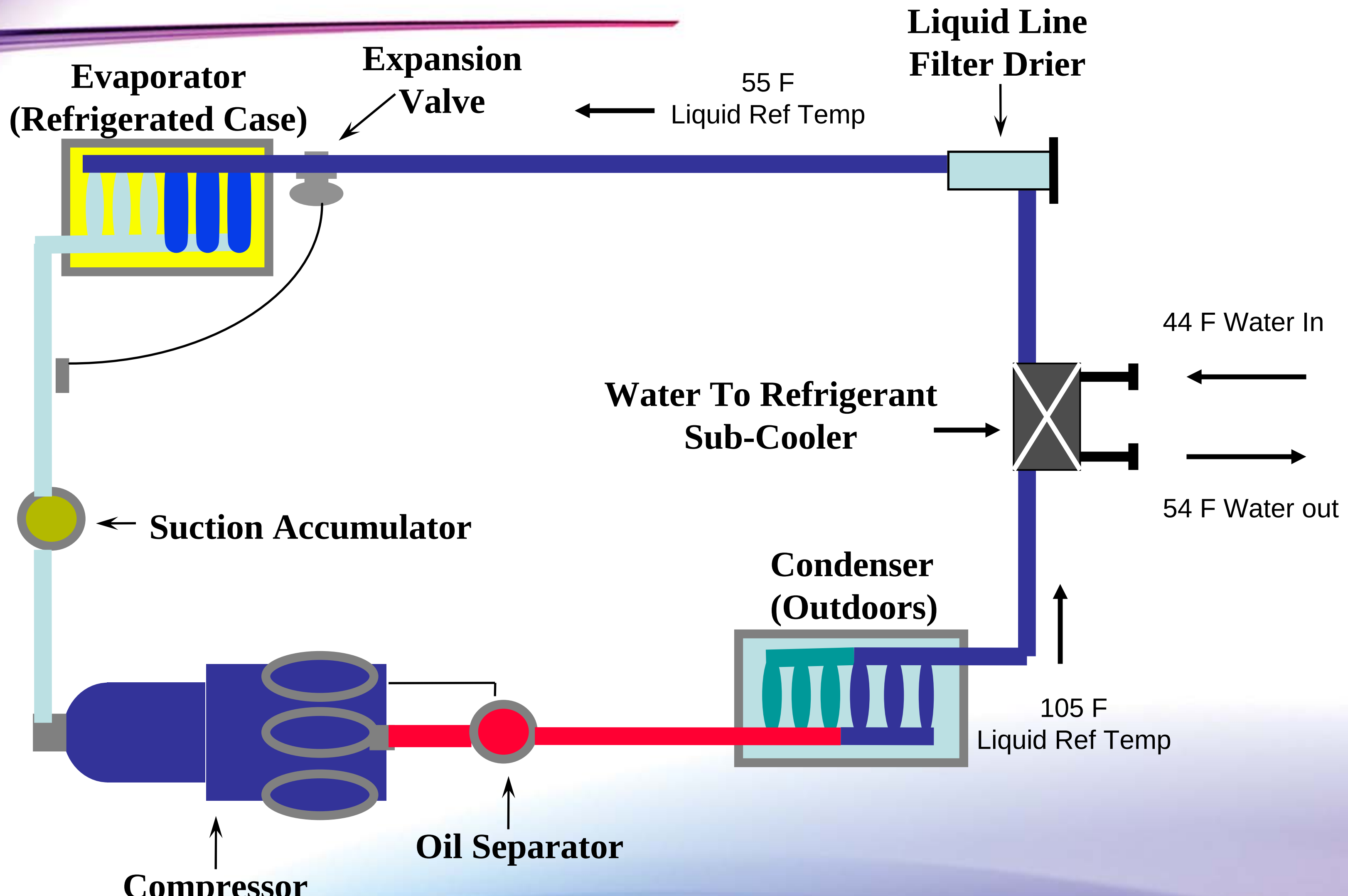
SUPERMARKET APPLICATION

RADIANT FLOOR HEATING

- **Radiant floor heating coils in checkout and frozen grocery sections in the stores.**
- **Benefits**
  - **Energy savings due to fuel cell low grade heat usage.**
  - **Aisles near refrigeration cases will require heating all year around.**

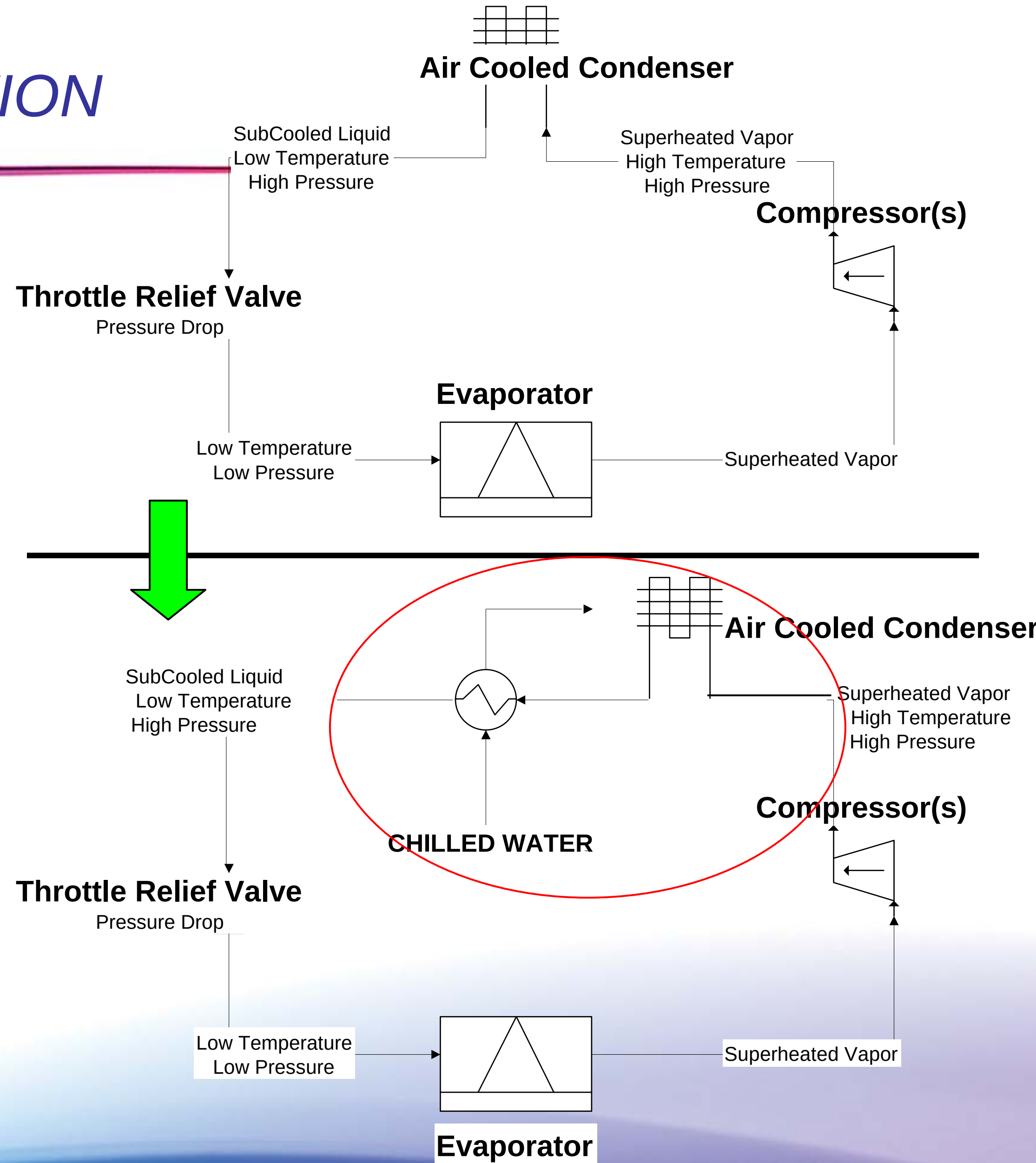
REFRIGERATION INTEGRATION

Energy Productivity, Security, Responsibility



SUPERMARKET APPLICATION

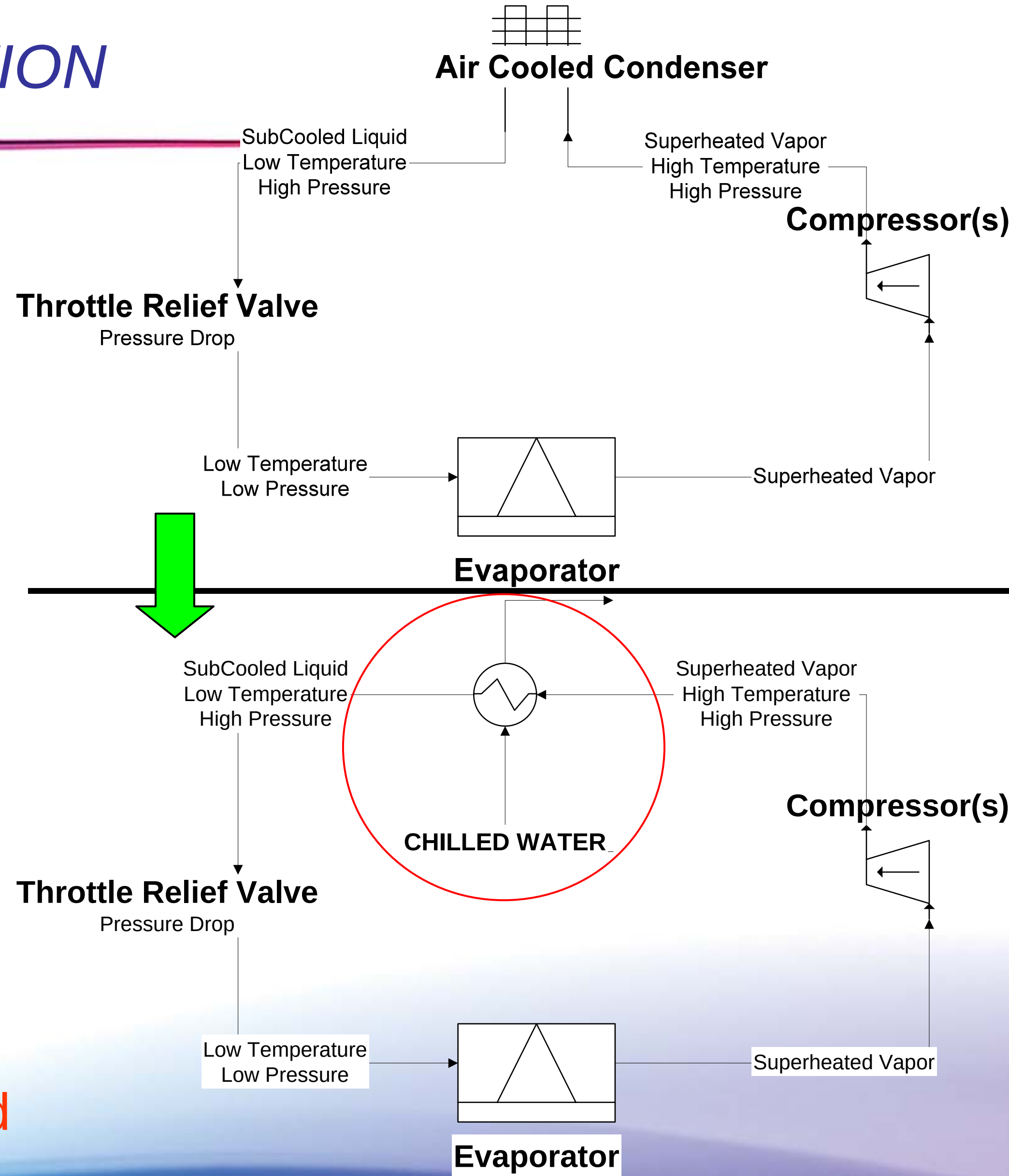
REFRIGERATION



- **Custom design <u>sub-cooling</u> the air cooler condenser with water cooled heat exchanger.**
- **Benefits**
  - **Lower electricity consumption (# of compressors)**
  - **More efficient operating point**
  - **Energy savings due to fuel cell heat usage**

SUPERMARKET APPLICATION

REFRIGERATION



- **Custom design replacing the <u>air cooler condenser</u> with water cooled condenser.**
- **Benefits**
  - **Lower electricity consumption (# of compressors)**
  - **More efficient operating point**
  - **Energy savings due to fuel cell heat usage**

*Electric Back Up Chiller Required

CT Value Proposition

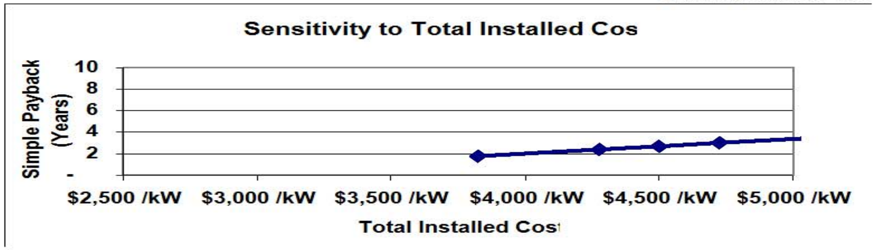
Energy Productivity, Security, Responsibility

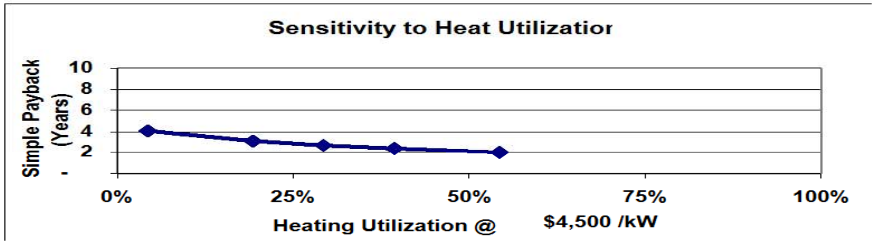
UTC Power
A United Technologies Company

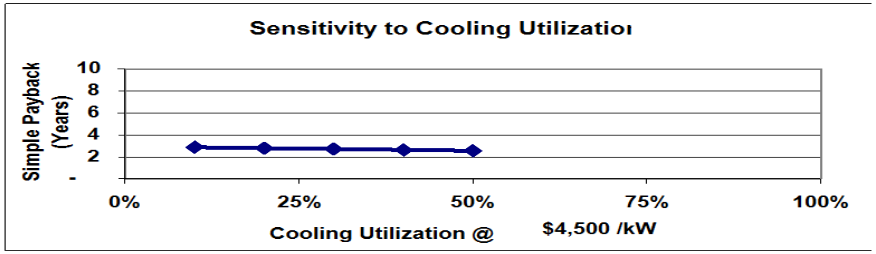
On-Site Power QUALIFYING BUDGETARY ESTIMATE

QBE Proforma DRAFT R9

Customer:	North Branford, CT	
Location:	CT	
Sales Lead:	McCullough	
Date:	5/13/2008	
UTC Power Solution:	**PureCell Model 400**	
Quantity:		1
Electrical Capacity (Net):		400 kW
Heating Capacity:		1,707 MBH
Cooling Capacity:		46 RT
Fuel Rate (HHV):		3.79 MMBTU/hr
System Utilization		
Electrical Utilization:		80%
Heat Utilization:		29%
Cooling Utilization:		30%
Facility Data		
Electric Energy Rate:		14.20 ¢/kWhr
Heating Fuel Rate:		$14.33 /MMBTU
CHP Gas Rate:		$11.50 /MMBTU
Simple Payback		
Total Installed Cost	$4,500 /kW	$1,800,000
State Grant	$2,500 /kW	($1,000,000)
Federal Investment Tax Credit	$1,000 /kW	($240,000)
Net Installed Cost	**$1,400 /kW**	**$560,000**
Year 1 Annual Savings		
Avoided Electric Energy:	2,663,040 kWh	$378,152
Avoided Heating Fuel:	5,775 MMBTU	$82,758
Avoided Cooling:	133,854 kWh	$19,007
RECs:	2.5 ¢/kWhr	$87,600
CHP Gas:	25,222 MMBTU	($290,051)
Service Contract:	2.0 ¢/kWhr	($70,080)
Net Annual Savings (Year 1)		**$207,385**
Simple Payback (years)		**2.7**







All assumptions and results contained herein are non-binding to UTC Power. Actual performance, economic return and environmental benefits are subject to change based on, among other variables, equipment performance, economic variables, actual operating and environmental conditions, capacity utilization and maintenance. This Savings and Payback pro-forma is for customer informational purposes only and does not constitute an equipment, installation or maintenance quotation or a commitment, representation or warranty that the forecasted savings or performance will be achieved. All commitments, representations and warranties with respect to UTC Power's equipment and services shall be solely as stated in the final contract for such equipment or services.

CT Value Proposition

Energy Productivity, Security, Responsibility

Avoided Emissions

Customer:	North Branford, CT
Location:	CT

Date: 5/13/2008

System:	PureCell Model 400
Heat Utilization:	29%
Cooling Utilization:	30%
Grid Region:	U.S.
Heating Fuel:	Natural Gas

Annual Emissions Balance Sheet	*Energy Balance* Grid Electricity (kWh)	Fuel (MMBTU)	*Emissions Balance* CO2	NOx (metric tons - MT)	SOx
Facility	(2,796,894)	(5,775)	(2,038)	(3.99)	(6.92)
On-Site Power System	0	25,222	1,335	0.04	0.00
BALANCE	***(2,796,894)***	***19,447***	***(704)***	***(3.94)***	***(6.92)***

Emissions Summary	*Emissions Reduction* MT	Equivalence	%
CO2	704	162 acres of trees	35%
NOx	3.94	226 cars	99%
SOX	6.92		100%

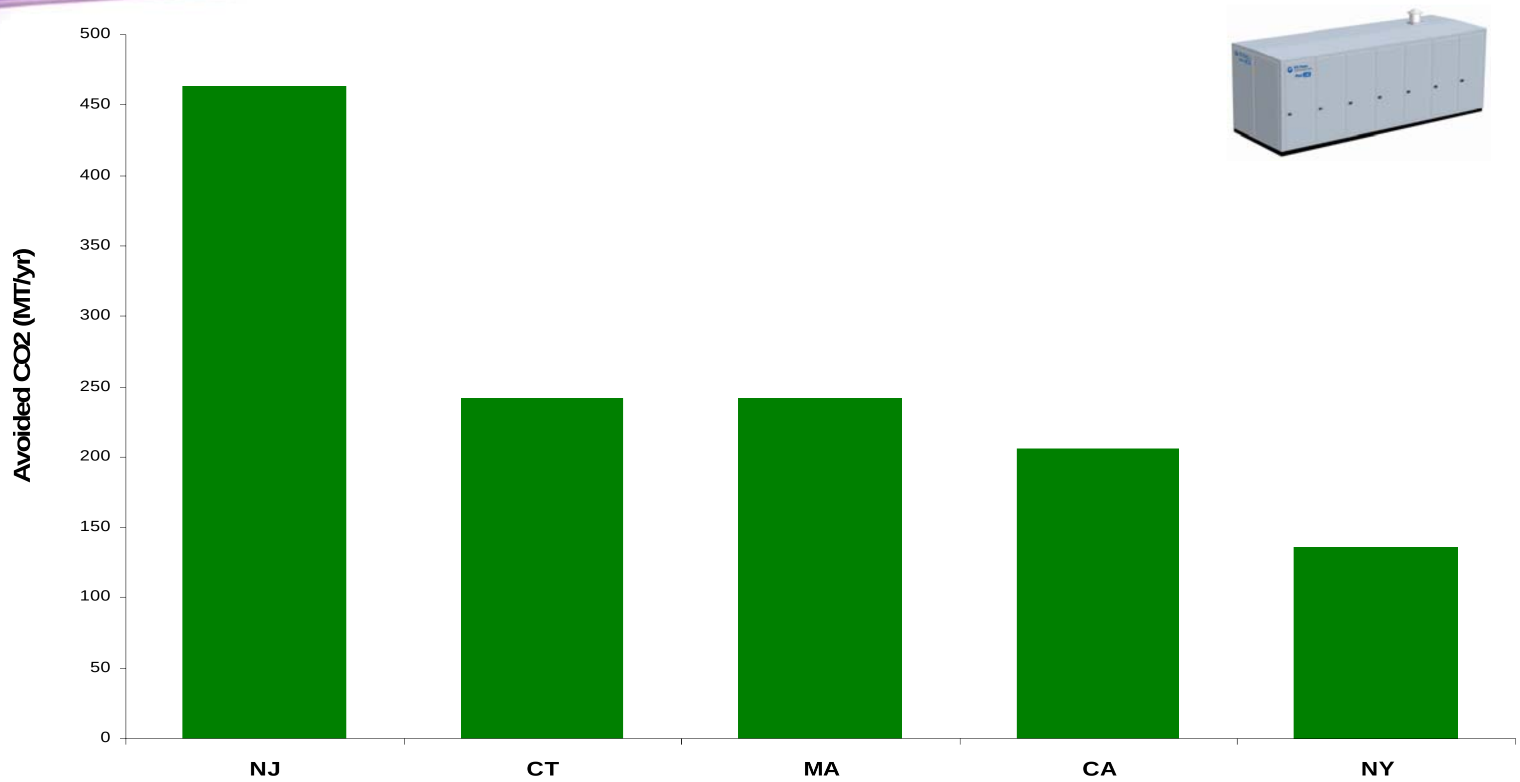
CO2 Emission Rate (kg/MWh)
297

project specific w/ heat recovery

Energy Responsibility

Energy Productivity, Security, Responsibility

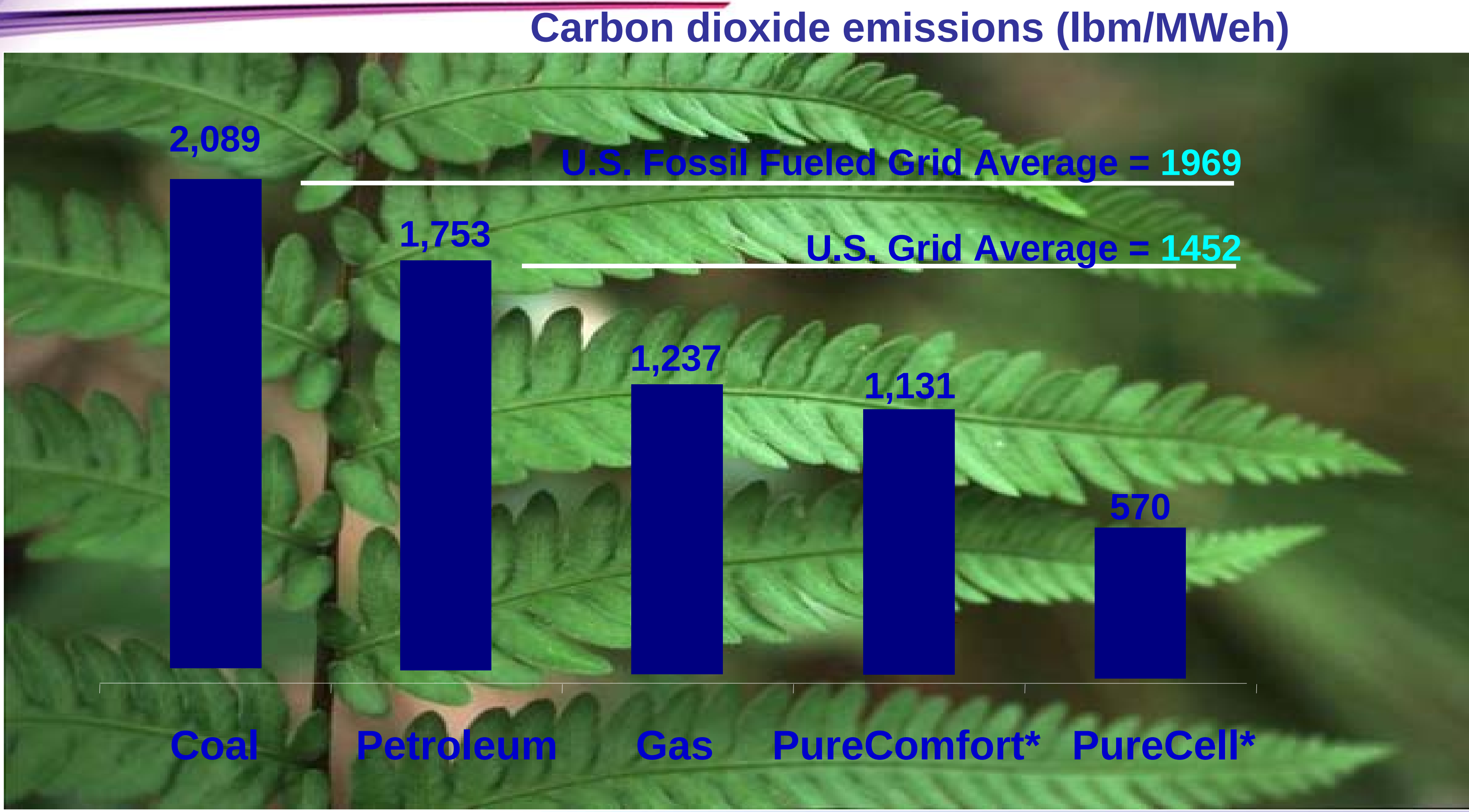
Typical avoided CO_2 emissions



Energy Responsibility

Energy Productivity, Security, Responsibility

Greenhouse Gas Reduction



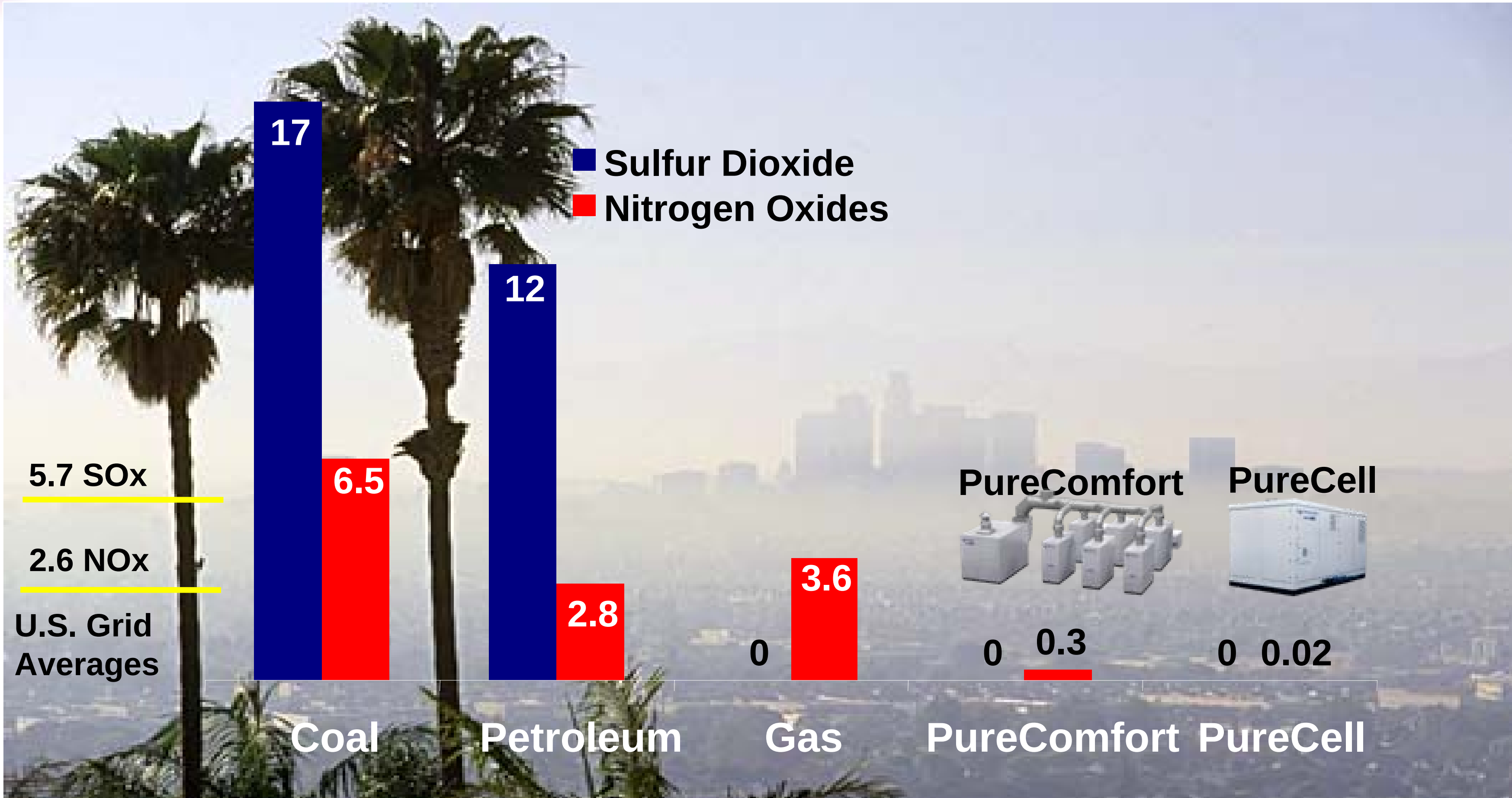
Source: US DOE EIA (Electricity Generation & Environmental Externalities, 2002) *Note: Assumes full utilization of heat with cooling

Energy Responsibility

Energy Productivity, Security, Responsibility

Air Pollutants (NOx,SO_2, lbm/MWh)

Central Power Plant vs. On-Site Power Emissions

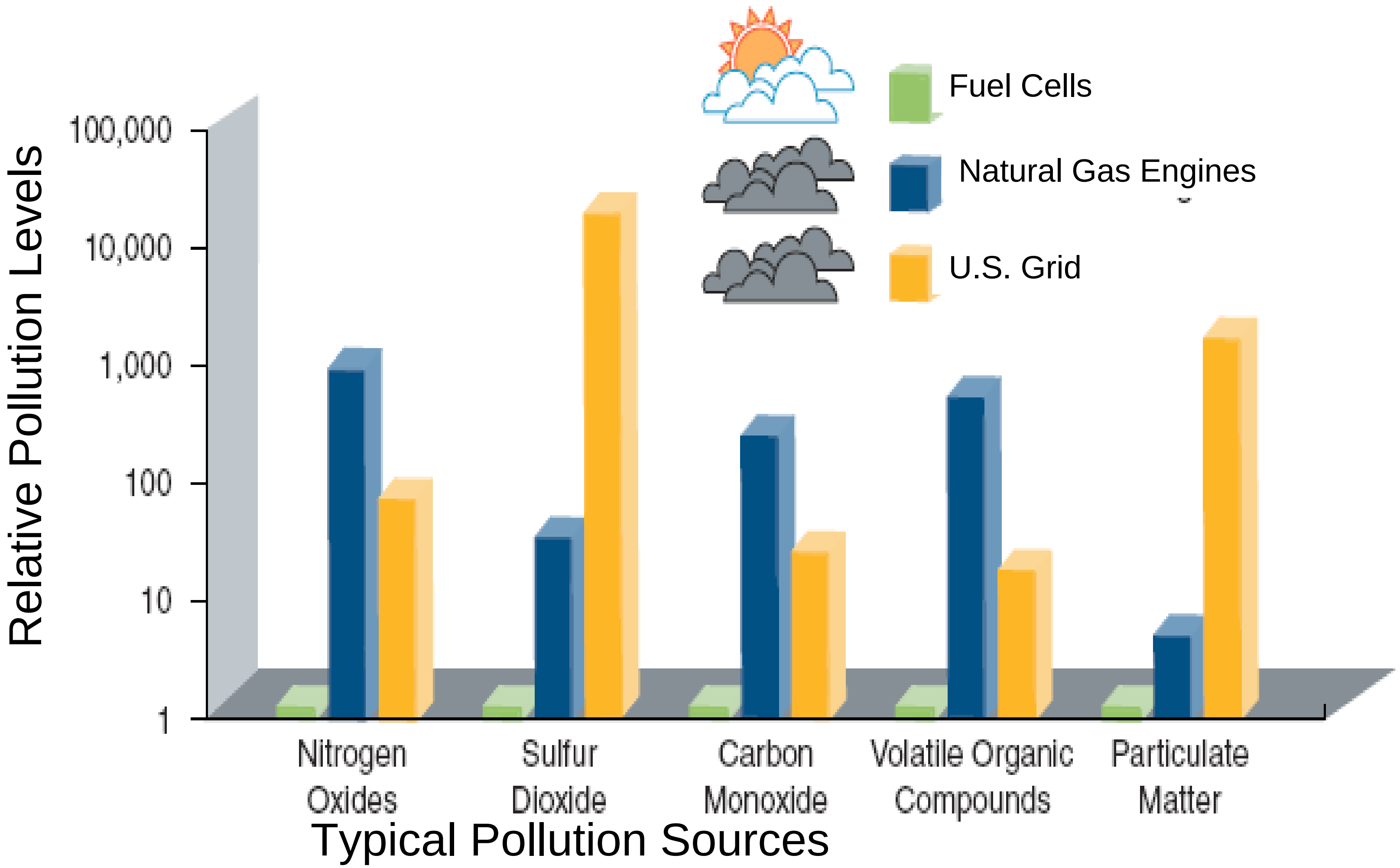


Source: US DOE EIA (Electricity Generation & Environmental Externalities, 2002)

Energy Responsibility

Energy Productivity, Security, Responsibility

Clean, efficient power generation



Fuel Cell Opportunities

Energy Productivity, Security, Responsibility

- *Energy Productivity*
  - Up to 90% Usage
    - Resource Efficiency
- *Energy Security*
  - Secure Power
    - Confidence
- *Energy Responsibility*
  - Environmental Footprint
    - Pure

TRUE GREEN TECHNOLOGIES

Willis L McCullough
UTC POWER
willis.mccullough@utcpower.com

FUEL CELLS/MICRO TURBINES/GEO THERMAL POWER

QUESTIONS?

Thank You