Overview of Stationary Fuel Cell Systems

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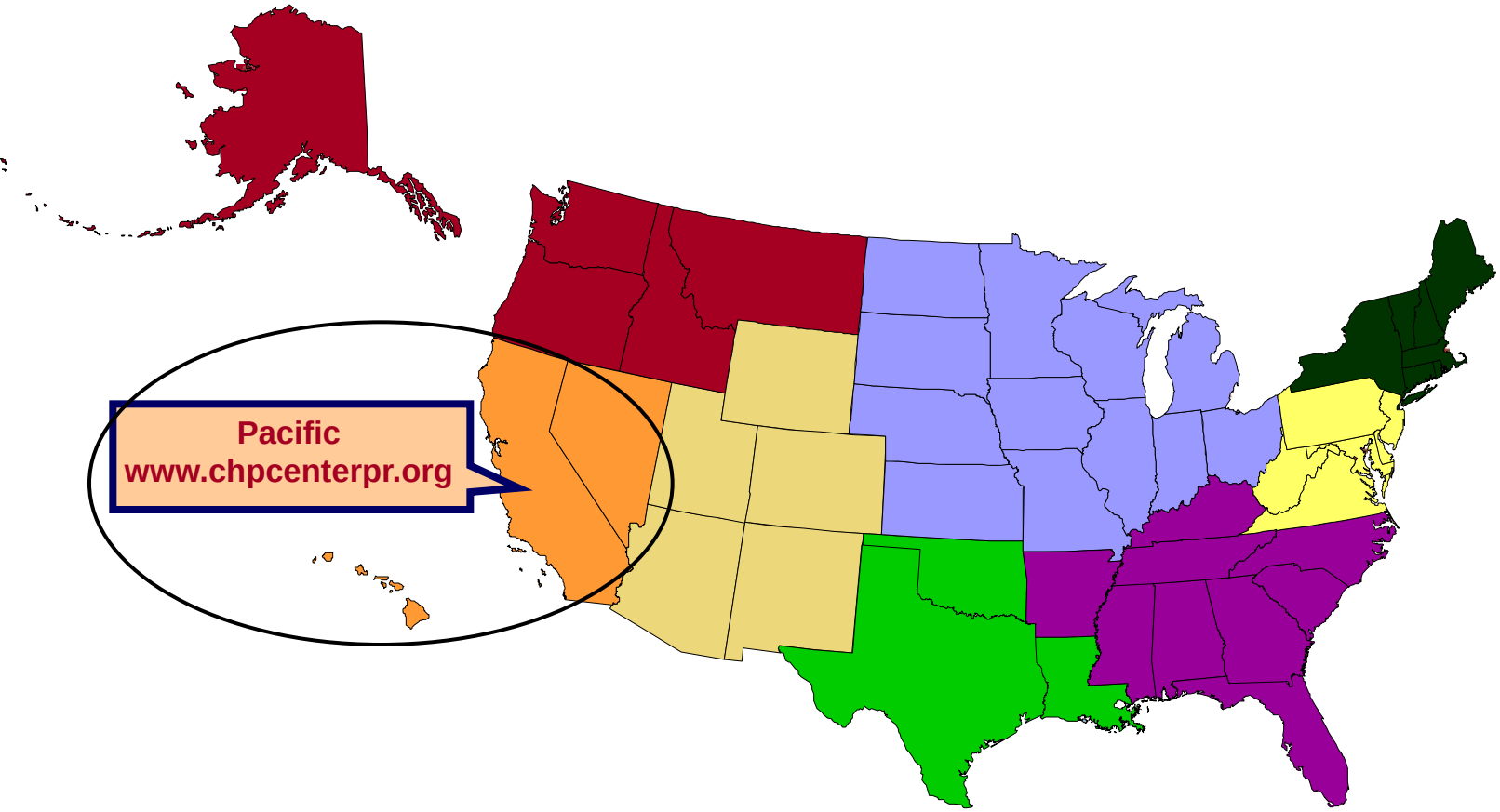
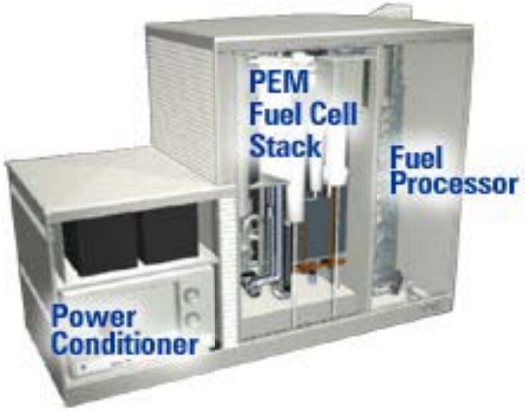


Stationary Fuel Cells

- 1 kW - 3+MW
  - Many different applications/niches
- Installed Cost
  - $4,500 to $30,000/kW
  - Incentive Programs in Many States
- Emissions
  - Very Low
- O&M Costs
  - Warranty Issue Now
- Efficiency 35-60%
  - Fuel to Electricity (up to 90%+ overall)
- Quiet Operation
- Design Life 5+ Years*
  - Stack Replacements are Significant O&M Cost
  - Data Scarce on Actual Degradation Rates
- Baseload or Load Following Depending on Cell Type

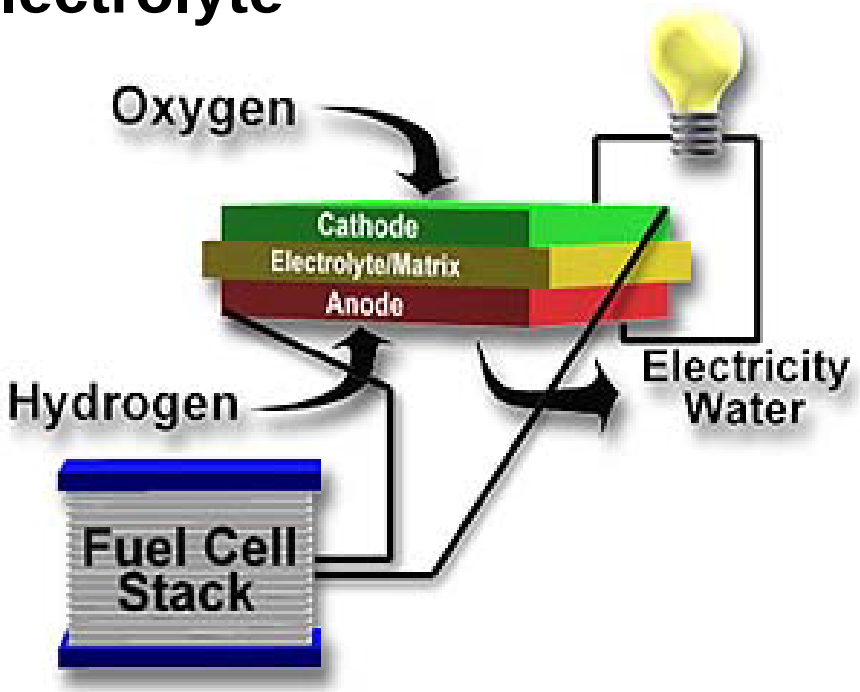


***UTC Fuel Cells, Fuel Cell Energy, Bloom Energy, Ballard Power Systems, Plug Power, Altergy Systems, Idatech, Jadoo Power, and others offer commercial products today but with varying performance and durability guarantees**

Stationary Fuel Cells: Operation

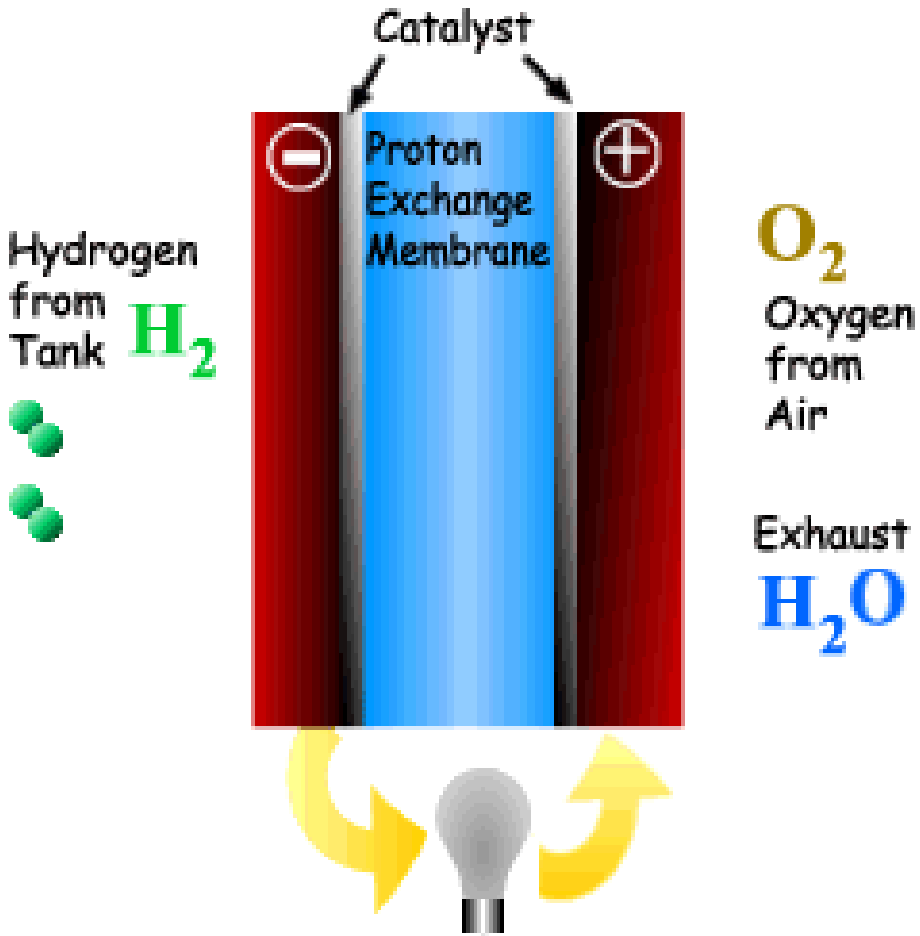
Basic Process: Fuel Cell

- "Continuous Battery"
- Fuel And Oxidant (Air) Supplied to Separate Chambers - Never Needs Charging
- Ionic Transport Through Electrolyte
- Reverse Electrolysis



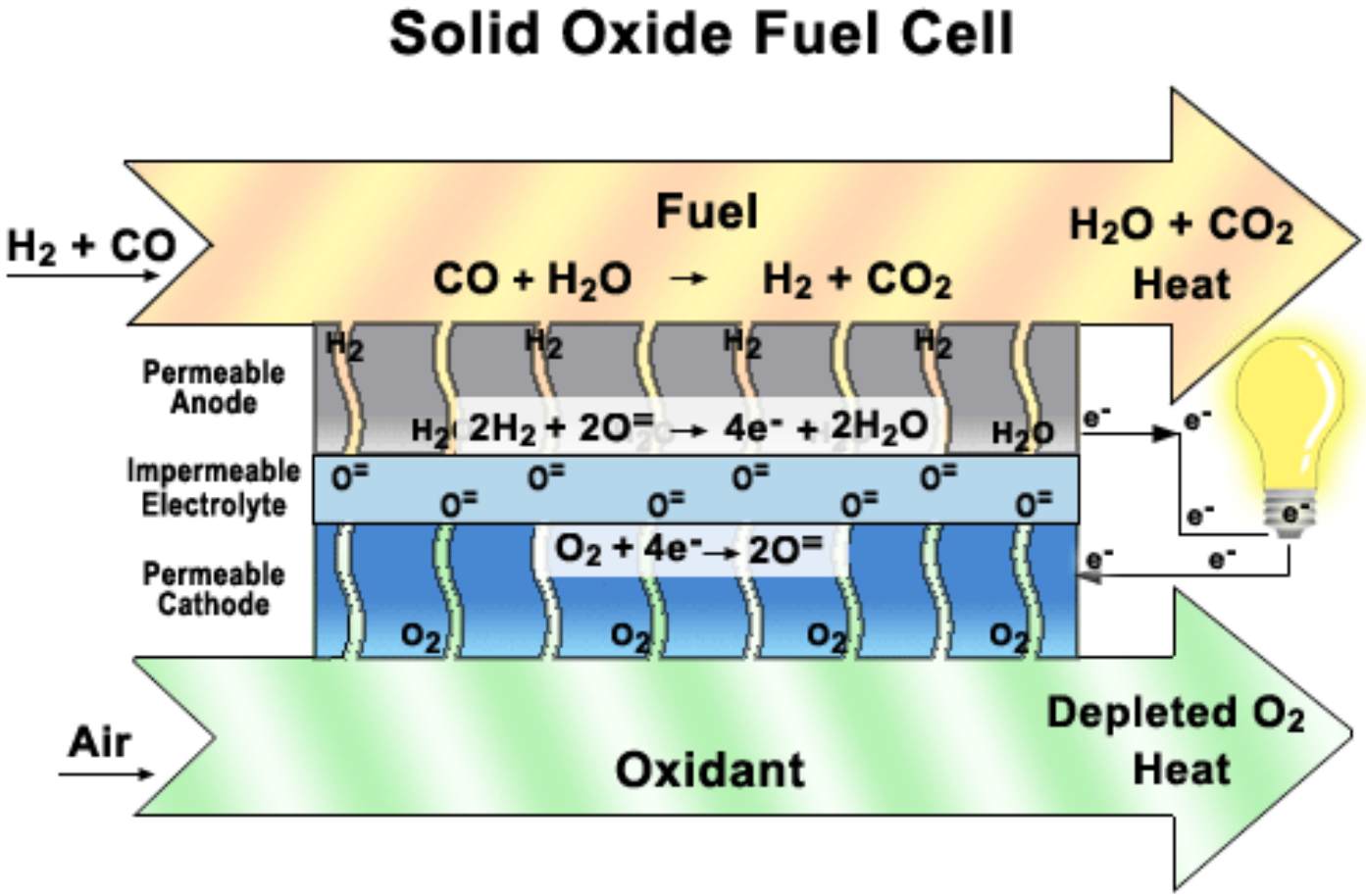
Stationary Fuel Cells: Operation

Basic Process: Fuel Cell



Stationary Fuel Cells: Operation

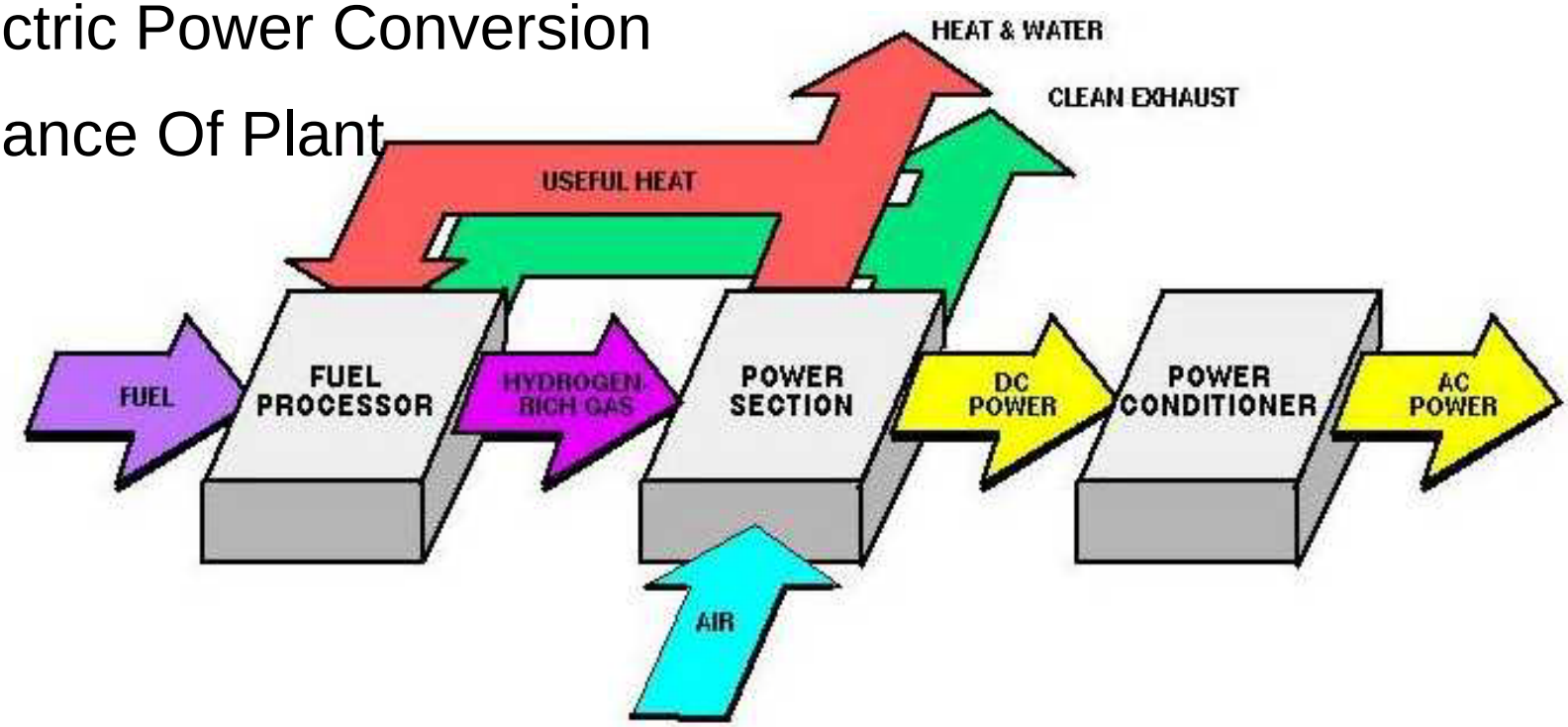
Basic Process: Fuel Cell



Stationary Fuel Cells: Operation

Basic Process: Fuel Cell

- Fuel Cell Stack
- Fuel Processing
- Electric Power Conversion
- Balance Of Plant

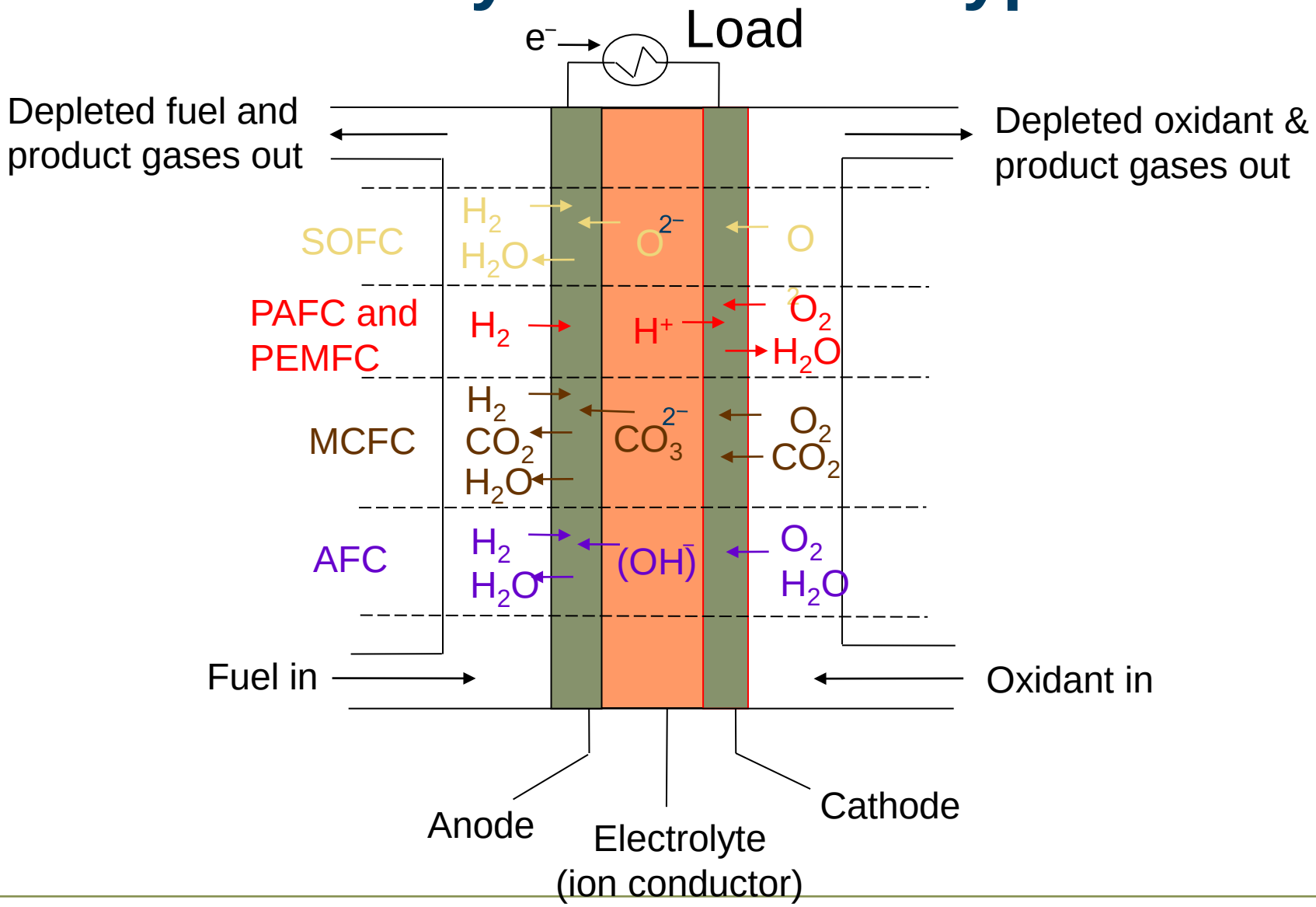


Stationary Fuel Cells: Types

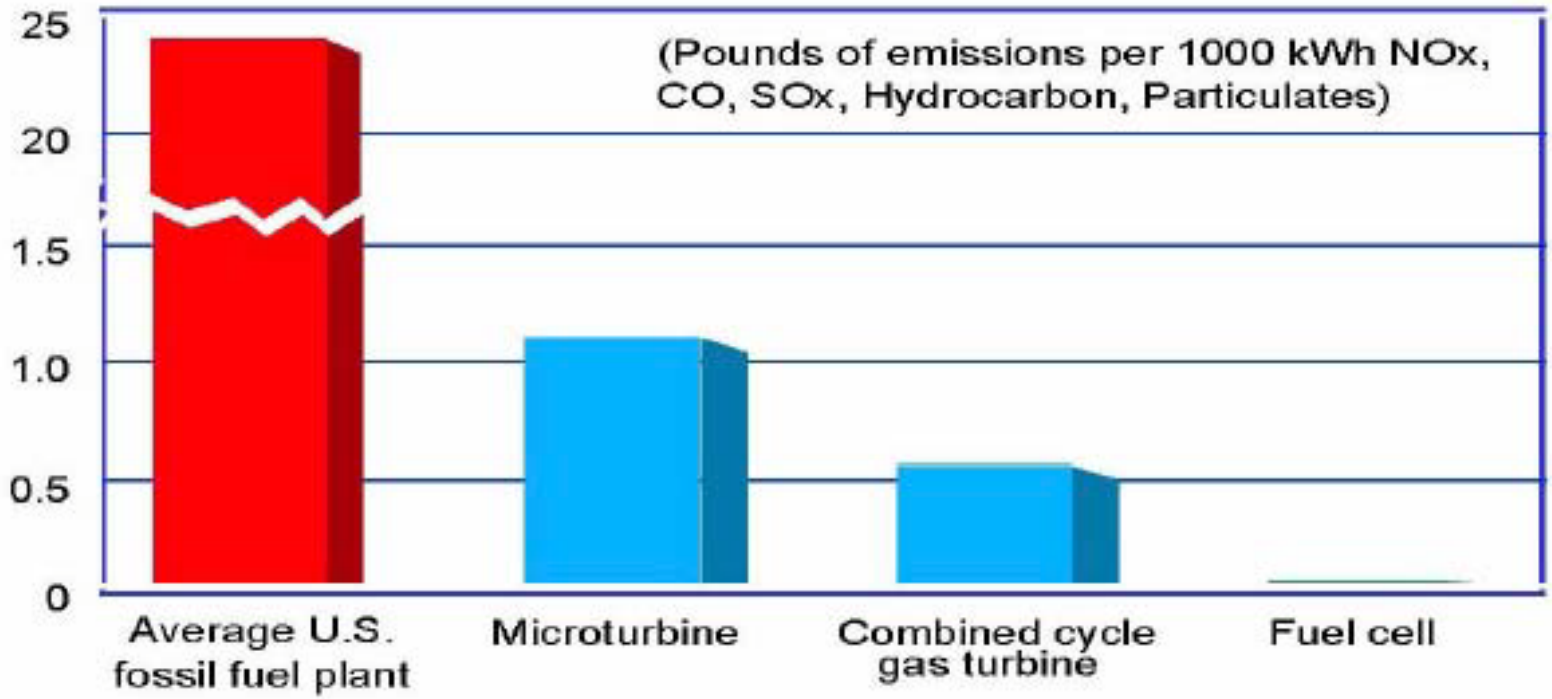
- Various *types* of Fuel Cell technology
- Named to reflect electrolyte material

	PAFC	MCFC	SOFC	PEMFC	AFC
Electrolyte	H_3PO_4	Molten Carbonate Salt	Ceramic (YSZ)	Sulfonic -acid Polymer (Nafion™)	KOH/H_2O
Operating Temperature	~ 200°C	~ 650°C	800-1000°C	~ 80°C	60-80°C
Fuels	H_2/ Reformate	H_2/CO/ Reformate	H_2/CO/CH_4/ Reformate	H_2/ Reformate	H_2
Reforming	External	External/ Internal	External/ Internal	External	
Oxidant	O_2/Air	CO_2/O_2/ Air	O_2/Air	O_2/Air	O_2/Air
Electrical Efficiency (LHV)	40 - 47%	45 - 55%	50 - 60%	40 - 60%	50 - 60%

Stationary Fuel Cells: Types



DG Comparison: Emissions



- Source: www.fuelcells.org

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DG Comparison: Emissions

Emissions Analysis[24]	System 1	System 2	System 3	System 4	System 5	System 6
Electricity Capacity (kW)	200	10	200	300	1200	100
Electrical Efficiency (HHV)	33%	30%	35%	43%	43%	43%
Fuel Cell Type	PAFC	PEM	PEM	MCFC	MCFC	SOFC
Emissions						
NOx, (lb/MWh)	0.035	0.06	0.06	0.02	0.02	0.05
CO, (lb/MWh)	0.042	0.07	0.07	0.10	0.10	0.04
VOC, (lb/MWh)	0.012	0.01	0.01	0.01	0.01	0.01
~~CO2, (lb/MWh)~~	~~0.035~~	~~0.06~~	~~0.06~~	~~0.02~~	~~0.02~~	~~0.05~~

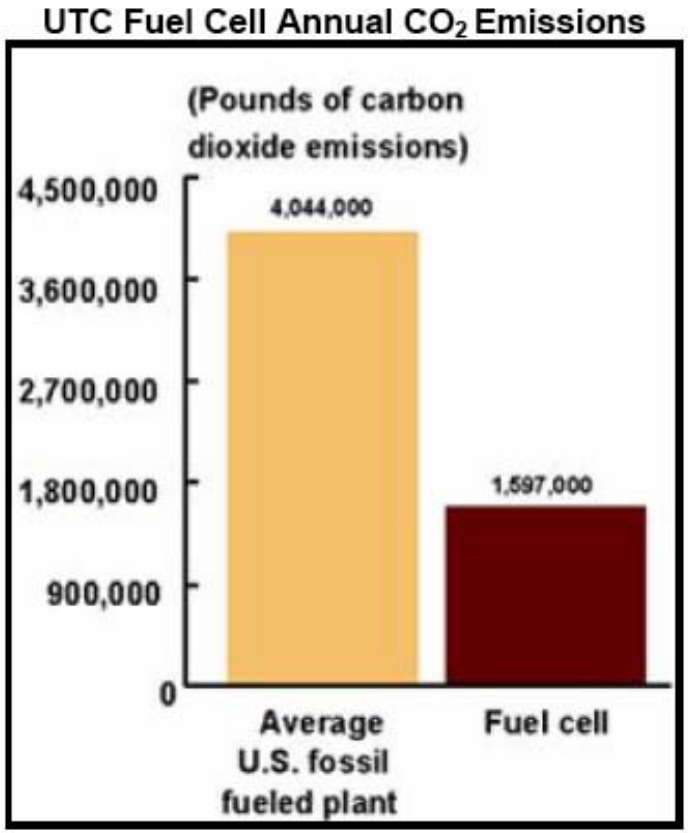
* *Electric only, for typical systems available or under development in 2007. Estimates are based on fuel cell system developers' goals and prototype characteristics. All estimates are for emissions without after-treatment and are adjusted to 15* percent O_2.

Source: Energy Nexus Group

For NOx, compare with *new* pulverized coal plant target of about 0.61 lb/MWh

Average current emissions are reported at 10x higher or around 6 lb/MWh NOx, according to U.S. EPA

DG Comparison: Emissions



- Source: United Technologies Corp.

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Stationary Fuel Cells: Economics

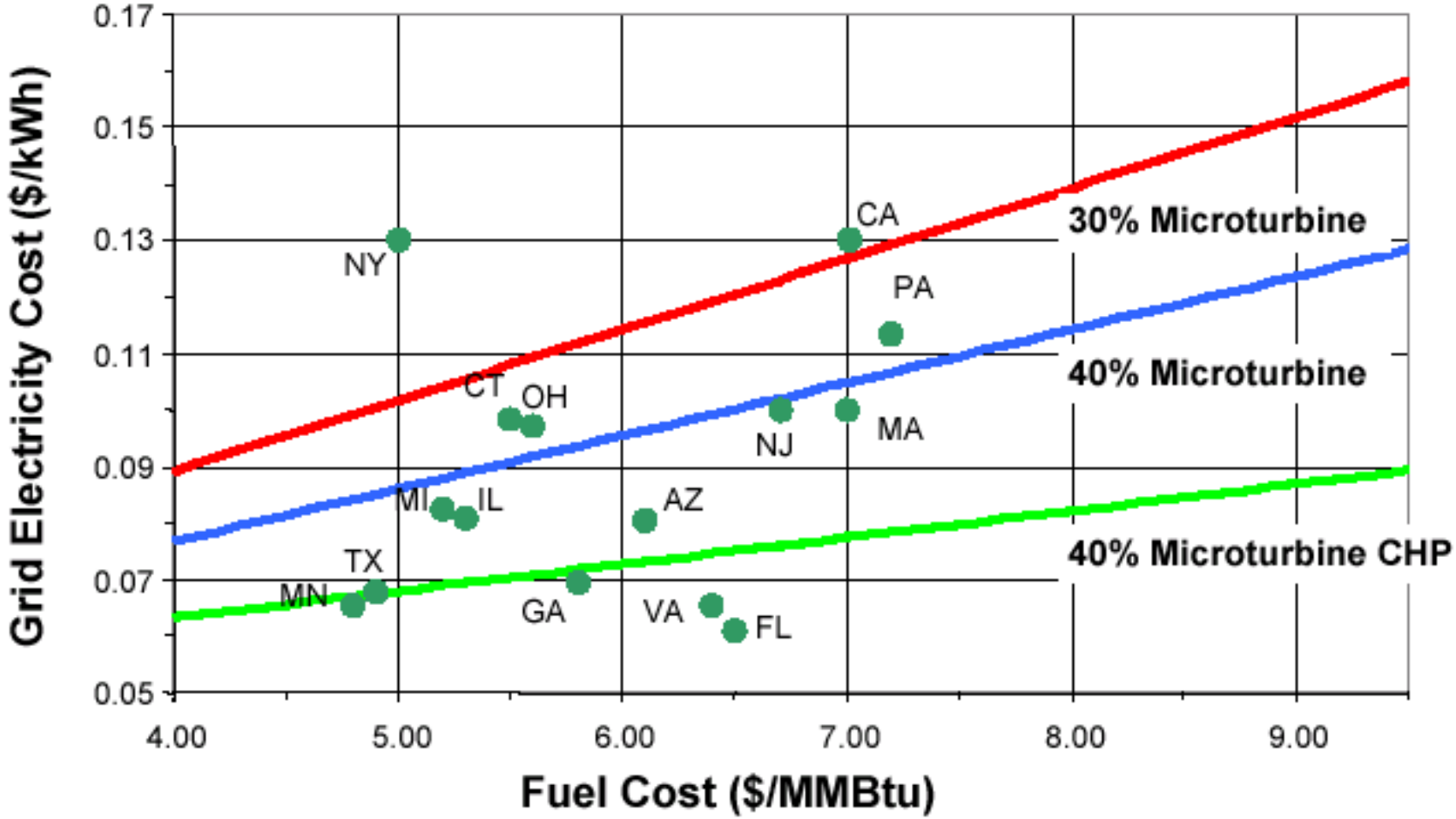
- Installed Capital Costs Are High
- For 200kW - 3MW Systems, $5,000/kW to $7,000/kW is Typical for Installed Cost
- ICF for DOE Recent Estimates:
  - PAFC 200-400kW: $6,300 / $7,000 (installed)
  - MCFC 300kW: $5,600 / $6,200 (installed)
  - MCFC 1500kW: $5,300 / $5,800 (installed)
- Buy-Down Programs and Other Incentives in Some States

Stationary Fuel Cells: Economics

- O&M Costs
  - Systems are not maintenance free and periodic stack replacements are required
    - Costs of $0.03-0.04/kWh are current estimates for O&M including stack replacements every 4-5 years
- Availability and economics
  - Availability can be significant factor in overall economics
    - ~95% availability is typical and achievable
    - Significant economic impact for down time in peak periods
      - Demand charges can be as high as $20-30/kW/month, and even 15 minutes of down time can have severe impact on monthly utility savings in some cases
    - Ownership and vested interest on part of customer can impact system reliability

General DG Economics

"Spark Spread"



T. Rosfjord, United Technologies Research Center

Policies for DG/CHP in CA

- Rule 21 Process for Interconnection
  - Streamlined process for utility interconnection that has reduced interconnection times since 2001
- CA PUC Self-Generation Incentive Program
  - Capital cost buy-down incentives for system installation:
    - $2,500/kW for stationary fuel cells
    - $4,500/kW for stationary fuel cells (renewable fuel)
  - Systems up to 3 MW qualify, with 100% incentive for first MW, 50% for second MW, and 25% for third MW
- New SGIP Program Plan Will Be Announced Soon
  - Technologies to be incentivized on performance basis
  - GHG Emission reductions and financial considerations will be key factors in determining incentive levels

Sierra Nevada Brewing Company Project

- 1 MW of molten carbonate fuel cells at Sierra Nevada Brewery in Chico, California
- Online in 2005
- $7 million project with approx. 5 year payback time (includes incentives)
- Brewery waste goes into aerobic digester to produce a hydrogen-rich gas
- Displacing about 25-40% of natural gas fuel input with digester gas

Santa Rita Jail Project

- 1 MW of molten carbonate fuel cells at Santa Rita jail in Dublin, CA
- Online in 2006
- $6.1 million project with approx. $2.4 million in incentives ($1.4 million SGIP and $1 million DoD)
- Long simple payback period of 13-14 years
- Heat recovery boosts overall efficiency to 70+%

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