Stationary Applications: Fuel Cells

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IPHE Integration and Liasion Committee

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Hydrogen Economy Concept

Biomass

Hydro

Wind

Solar

Nuclear

Oil

Coal

Natural Gas

Sequestration

Storage

H_2

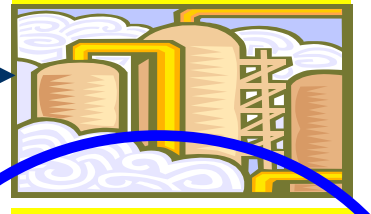
Delivery

Distributed Generation

Central Power Systems

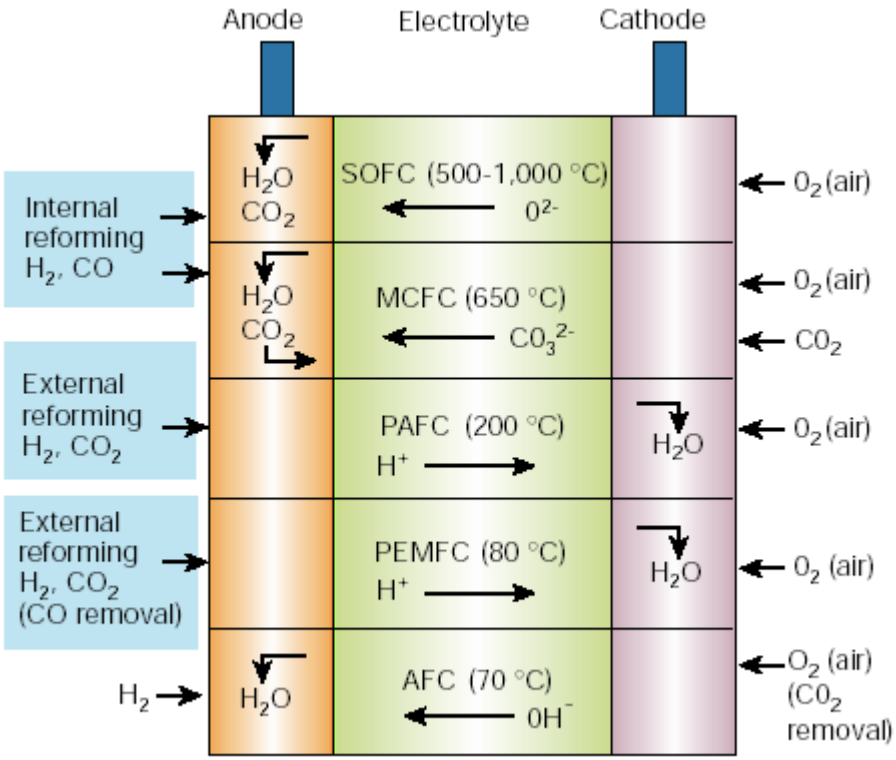
Transportation

Industry



Power Generation

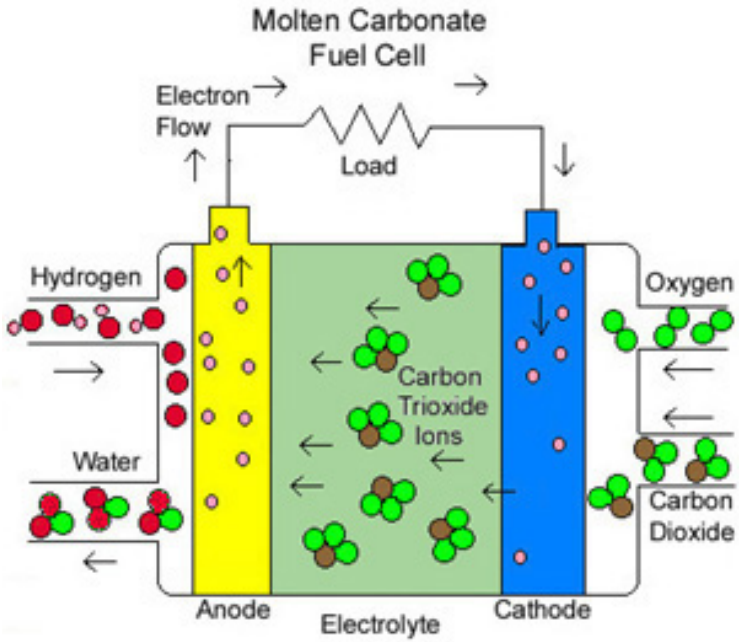
Types of Fuel Cells

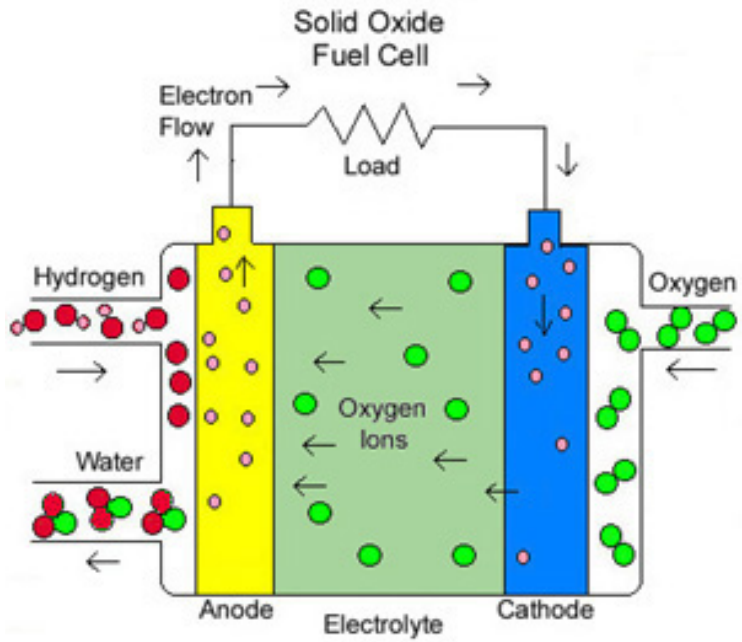


- Alkaline (AFC) developed for the Apollo program
- Polymer membrane (PEMFC) leading candidate for transportation
- Phosphoric acid (PAFC) were first units commercially available for combined heat and power (CHP)
- Molten carbonate (MCFC) and solid oxide (SOFC) can work directly with hydrocarbon fuels

Taken from B. C. H. Steele & A. Heinzel, Nature, 414 (2001) 345

Higher Temperature Fuel Cells





Molten potassium and lithium carbonates
600 ° C to 700 °C
CO_3^{2-} carrier
Nickel as catalyst
Stainless steel hardware
High temperature, corrosion, pumps

Zirconium dioxide ceramic
850 ° C to 1,000 °C
O^{2-} carrier
Perovskites as catalyst
Ceramic hardware
High temperature, fragile materials

Molten Carbonate Fuel Cell (MCFC)

- Fuel Cell Energy (FCE) is U.S. vendor for MCFC
- More than 32 stationary fuel cells, each with an output greater than 100 kW
  - North America: 18 installations
  - Europe: 9 installations
  - Asia: 5 installations
- Have generated more than 50 million kWh of electricity

FCE Core Products Characteristics

- High temperature, high efficiency, carbonate fuel cell power plants for base load commercial and industrial applications
- High value waste heat by-product for cogeneration
- Systems do not require a hydrogen infrastructure
  - DFC's generate hydrogen internally from readily available fuels such as natural gas
- Certifications for product safety, interconnection, performance and installation
- Meet customer expectations

DFC® 300

DFC® 1500

DFC® 3000

Multi-MW Grid Support

AEP Ohio Coal LLC

- Rose Valley site in Hopedale, OH
- 200 kW DFC
- Coal bed methane
- Funded by USDOE and AEP

Wabash River Energy, Ltd

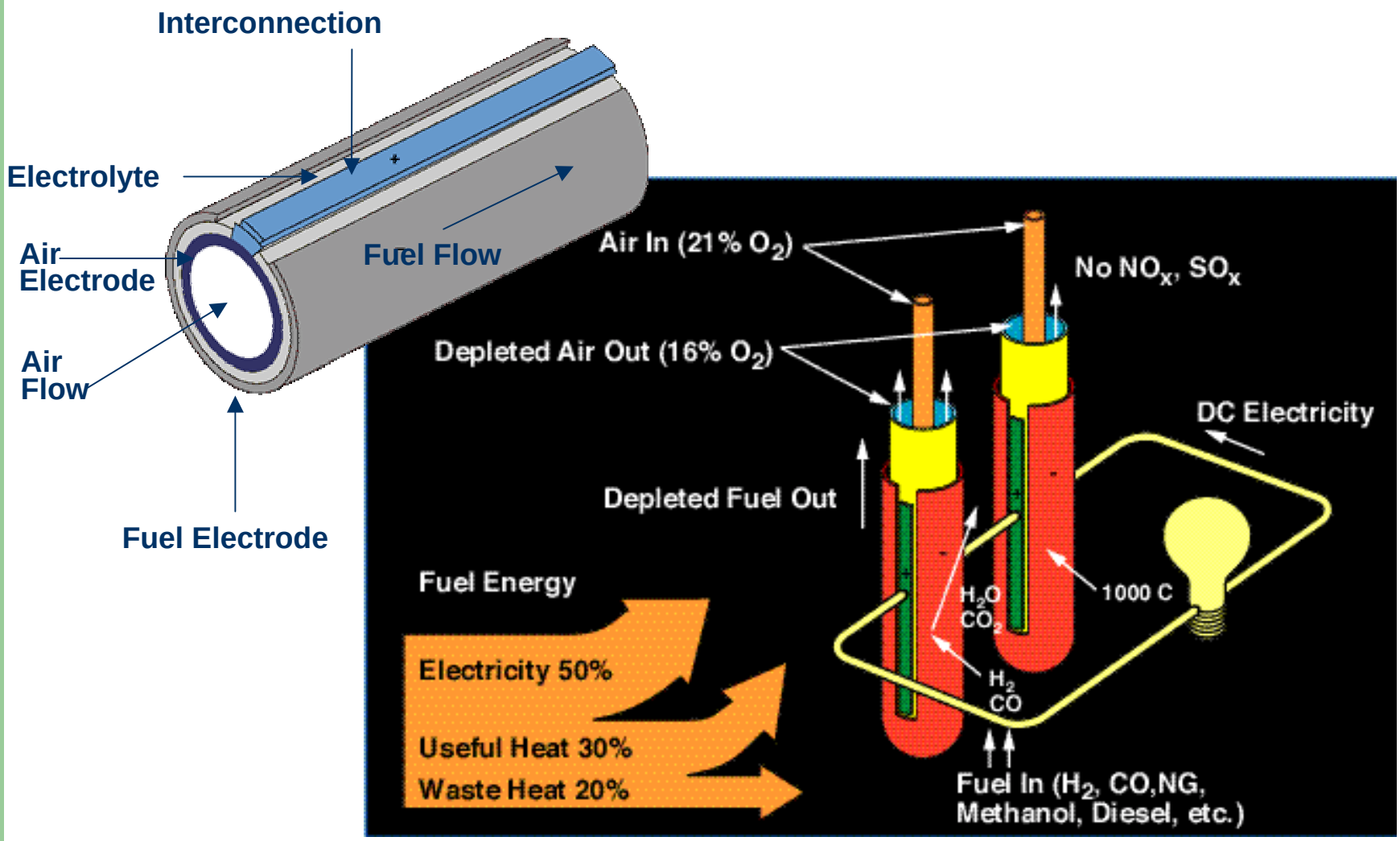
- Terre Haute, IN
- 2 MW DFC3000
- Coal-derived synthesis gas
- Global Energy, Inc., FuelCell Energy, and the USDOE

U.S. Tubular SOFC Technical History

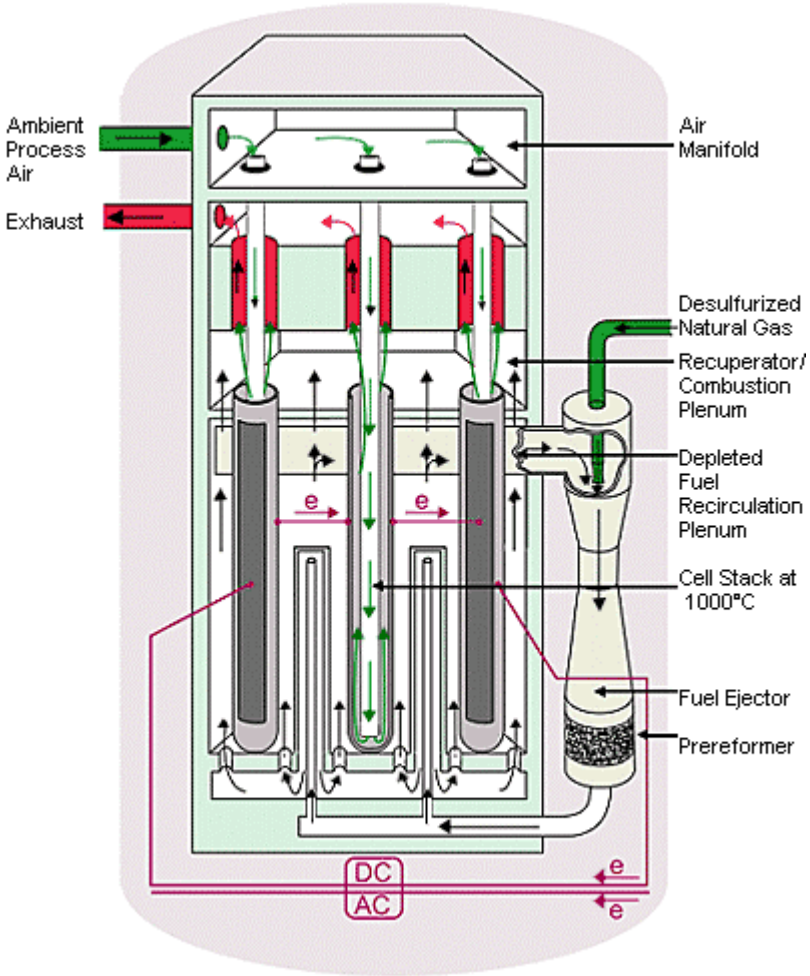
- Research and development started by Westinghouse in the early 1970s in Pittsburgh, Pennsylvania, and continued by Siemens after the acquisition of Westinghouse
- Partnership with US Department of Energy since 1980
- Significant investment by Westinghouse, Siemens, US DOE, other government entities and customers to develop SOFC technology
- Seventeen demo units shipped out of Churchill, Pennsylvania
- Since 1986 demonstration systems have accumulated 88,000+ hours of operation producing more than 4,000 megawatt hours of power with no appreciable degradation

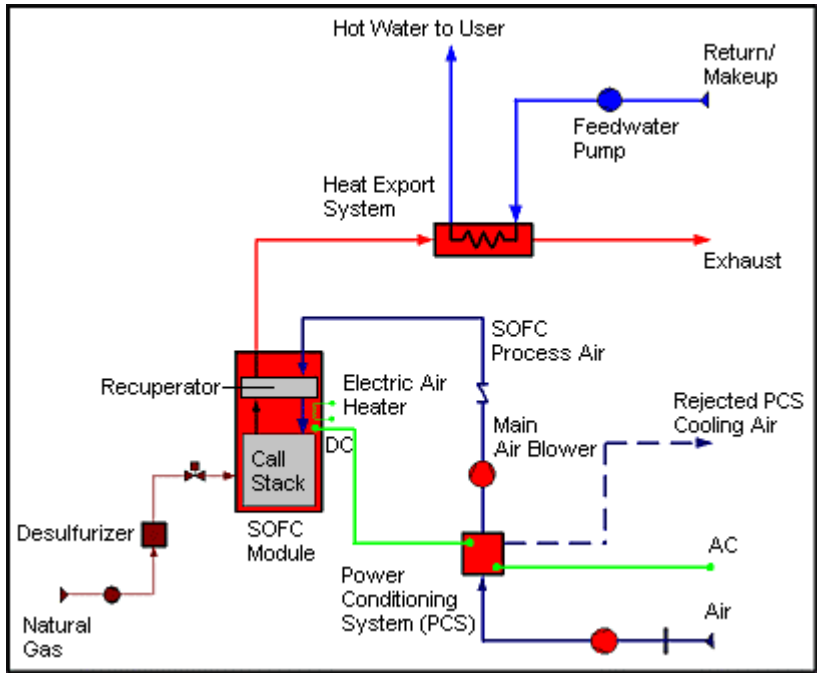
Siemens Westinghouse Power Corporation is a recognized world leader in solid oxide fuel cell technology

Siemens Westinghouse Tubular SOFC

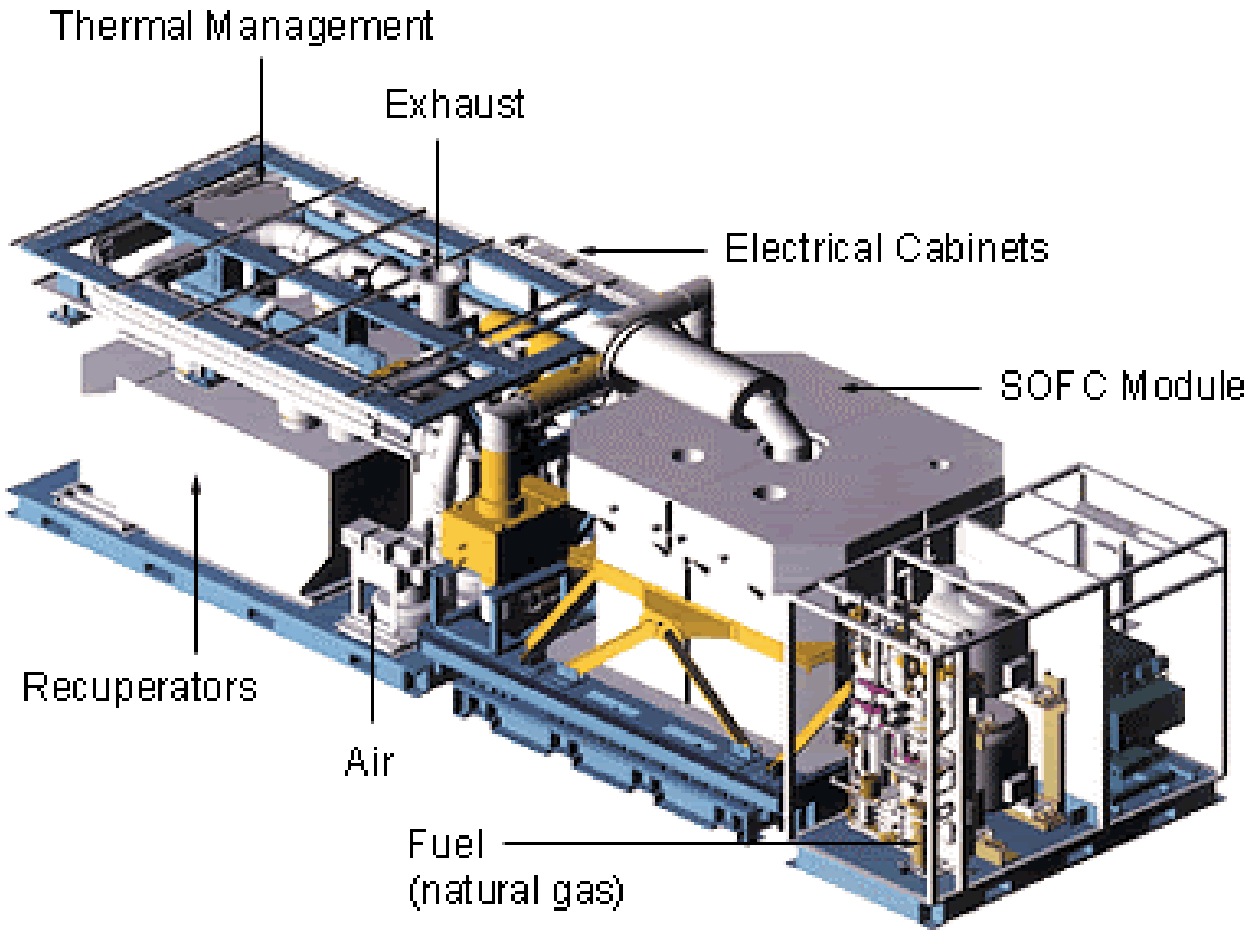


Combined Heat and Power (CHP)





CHP by Siemens Westinghouse



EDB/ELSAM CHP100 SOFC at NUON Site

Completed SOFC System Demonstration Programs

Westervort, The Netherlands

district heating

PNG fuel

16,610 hours

110 kWe to grid

46% Efficiency [net ac/LHV]

No Degradation

CHP100 SOFC at RWE Site

Completed SOFC System Demonstration Programs

Essen, Germany

district heating

PNG fuel

3,870 hours

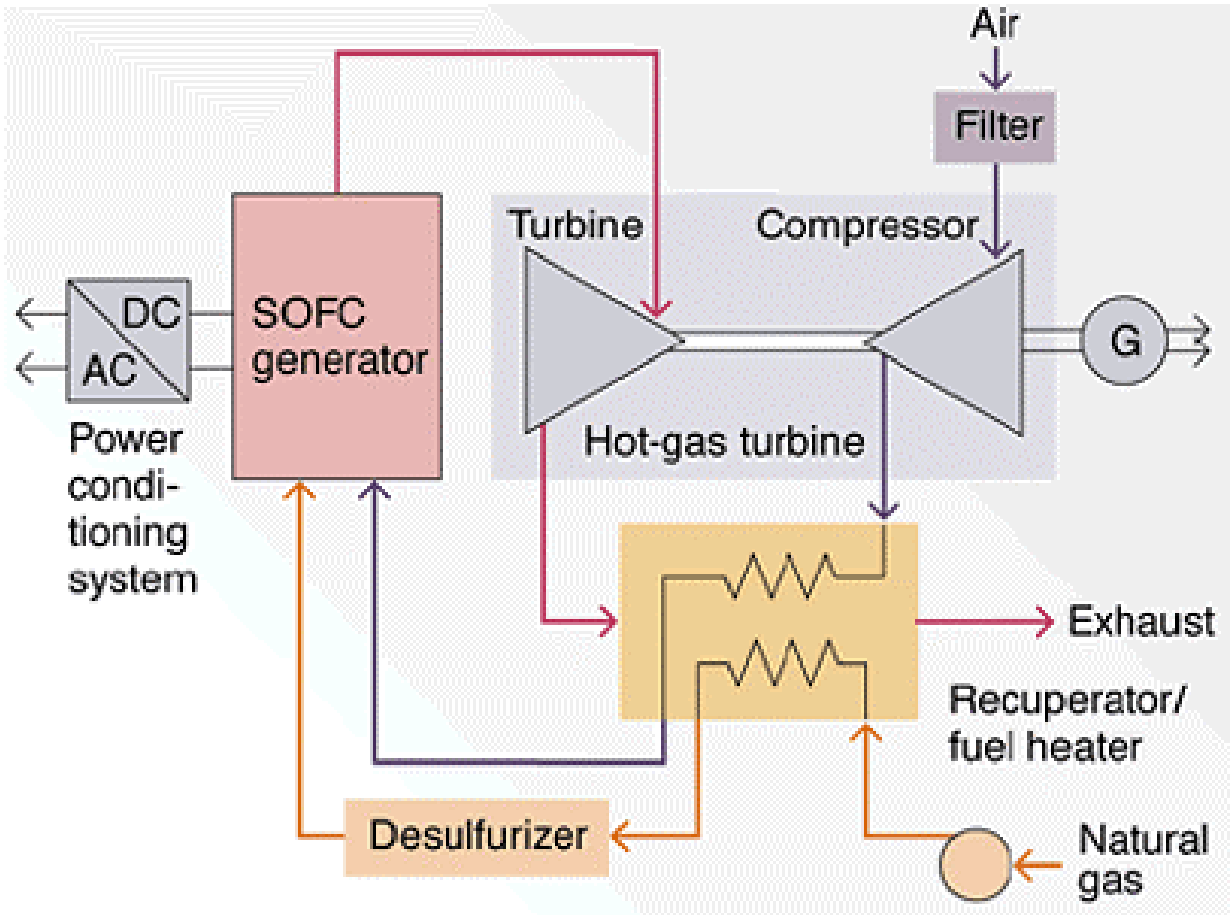
System Dimensions

Length = 8.6 m
Width = 2.8 m
Height = 3.7 m
Weight = 32,600 kg

Off Skid

PCS – [+1 m length & 3,000 kg]
HES
UPS

SOFC/Gas Turbine Hybrid

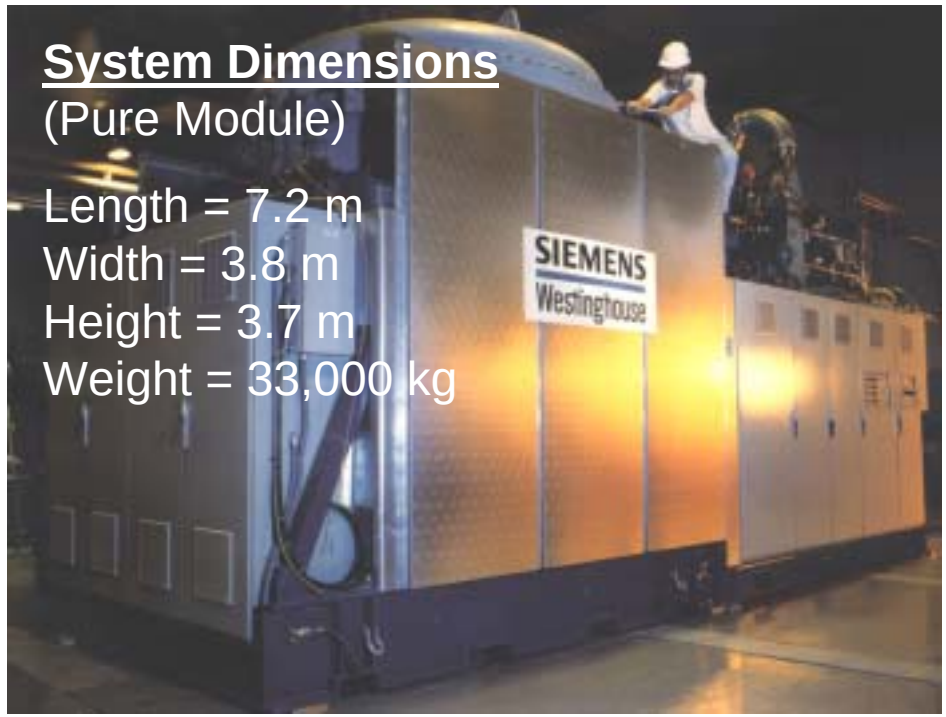


SOFC/Gas Turbine Hybrid Cycle Diagram

PH200 SOFC Proof-of-Concept for SCE

Southern California Edison
[SCE, DOE, SWPC, EPRI, CEC, SCAQMD, UCI-Irvine NFCRC]

- **Power Module**
  - **PSOFC**
  - **1152 cells**
  - **220 kWe**
  - **MTG [IRES]**
- **Off Skid**
  - **NG Compressor**
  - **Desulfurizer**
  - **Dissipator**
- **Operation**
  - **3000 hrs**
  - **η = 53% net ac**



PH300 Proof-of-Concept Power System

Under assembly in Pilot Manufacturing Facility

- **Power Module**
  - **PSOFC**
  - **1704 cells**
  - **300 kWe**
  - **MTG**
  - **Heat Export**
  - **Fuel Supply**
  - **Steam Supply**
- **Auxiliary Skid**
  - **PCS**
  - **Electricals**
- **Off Skid**
  - **NG Compressor**
  - **Desulfurizer**
- **Efficiency**
  - **η > 55% [Net_ac/ LHV]**

Stationary Applications: PEM Fuel Cells

Valri Lightner

Energy Efficiency and Renewable Energy

U.S. Department of Energy

Washington, DC

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FCE MCFC Installations: North America

- Yale University, New Haven, CT
- AEP Ohio Coal LLC, Hopedale, OH
- LADWP-Terminal Island, San Pedro, CA
- Wabash River Energy, Lts., Terre Haute, IN
- Coast Guard Air Station, Bourne, MA
- Ocean County College, Toms River, NJ
- Mercedes-Benz, Tuscaloosa, AL
- City of Westerville, Westerville, OH
- LADWP-Main St., Los Angeles, CA
- Caterpillar Technical Ctr., Peoria, IL
- Sheraton Hotel, Parsippany, NJ
- Zoot Enterprises, Bozeman, MT
- Sheraton Hotel, Edison, NJ
- LADWP-Headquarters Bldg., Los Angeles, CA
- King County Wastewater Treatment, Renton, WA
- Grand Valley State University, Muskegon, MI
- El Estero Wastewater Treatment Plant, Santa Barbara, CA
- Sheraton New York Hotel & Towers, New York, NY

FCE MCFC Installations: Europe

- RWE-Energy Park, Essen, Germany
- IZAR, Cartagena, Spain
- EnBW Michelin, Karlsruhe, Germany
- Gruenstadt Clinic, Pfalzwerke, Germany
- Vattenfall/BeWag-Utility, Berlin, Germany
- Deutsche Telecom, Munich, Germany
- IPF Magdeburg, Germany
- University of Bielefeld, Bielefeld, Germany
- Rhon-Klinikum Hospital, Ban Neustadt, Germany

FCE MCFE Installations: Asia

- Epson (2), Ina, Japan
- City of Fukuoka, Fukuoka, Japan
- Japex, Nagaoka City, Japan
- Kirin Brewery, Tokyo, Japan