

Status of Carbonate Fuel Cell Fueled by Gaseous Fuels

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Direct Carbon Fuel Cell Technology Workshop

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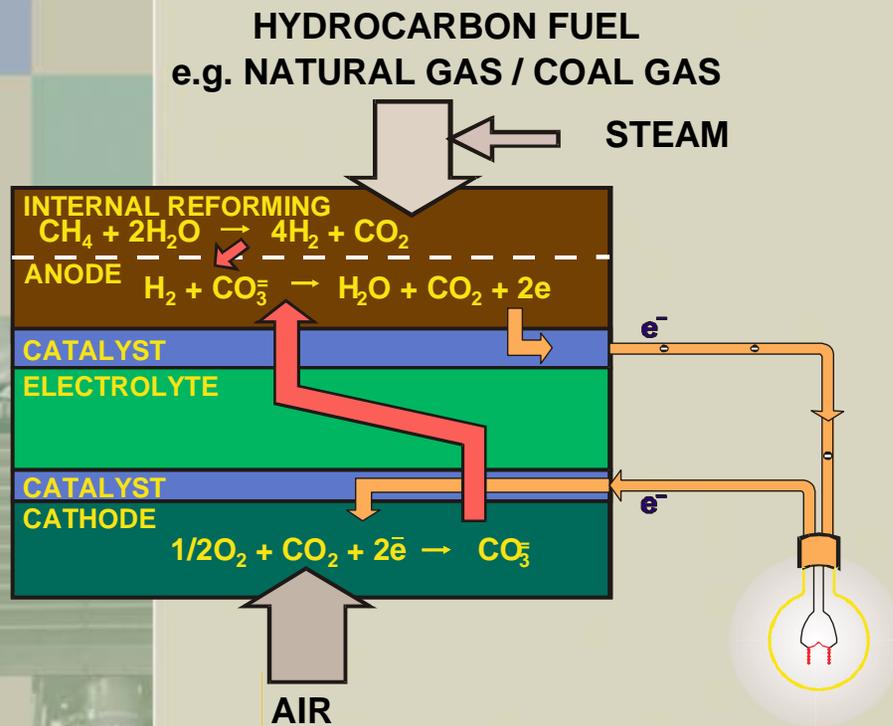
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DFC Technology

Direct FuelCell®

High Temperature Internal Reforming Direct FuelCell®



The Direct FuelCell® Advantage

- **Optimal Operating Temperature**
 - ◆ Uses commonly available materials
 - ◆ No noble metal catalyst
 - ◆ High temperature by-product heat
- **Internal Reforming**
 - ◆ H_2 generated internally
 - ◆ High efficiency
 - ◆ Simpler system
 - ◆ Negligible NO_x
 - ◆ Reduced cooling requirement
- **Atmospheric Pressure Operation**
 - ◆ Allows unattended operation
 - ◆ More reliable

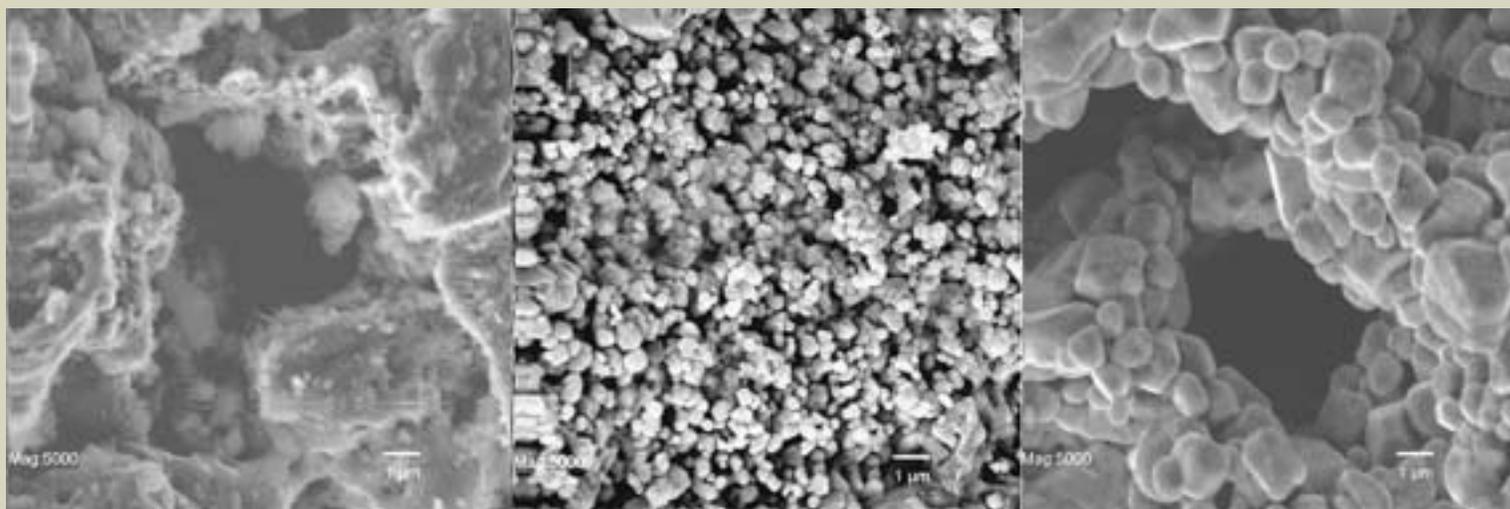
Morphology of Carbonate Fuel Cell Active Components

The fuel cell active components are made from inexpensive materials

Anode

Matrix

Cathode



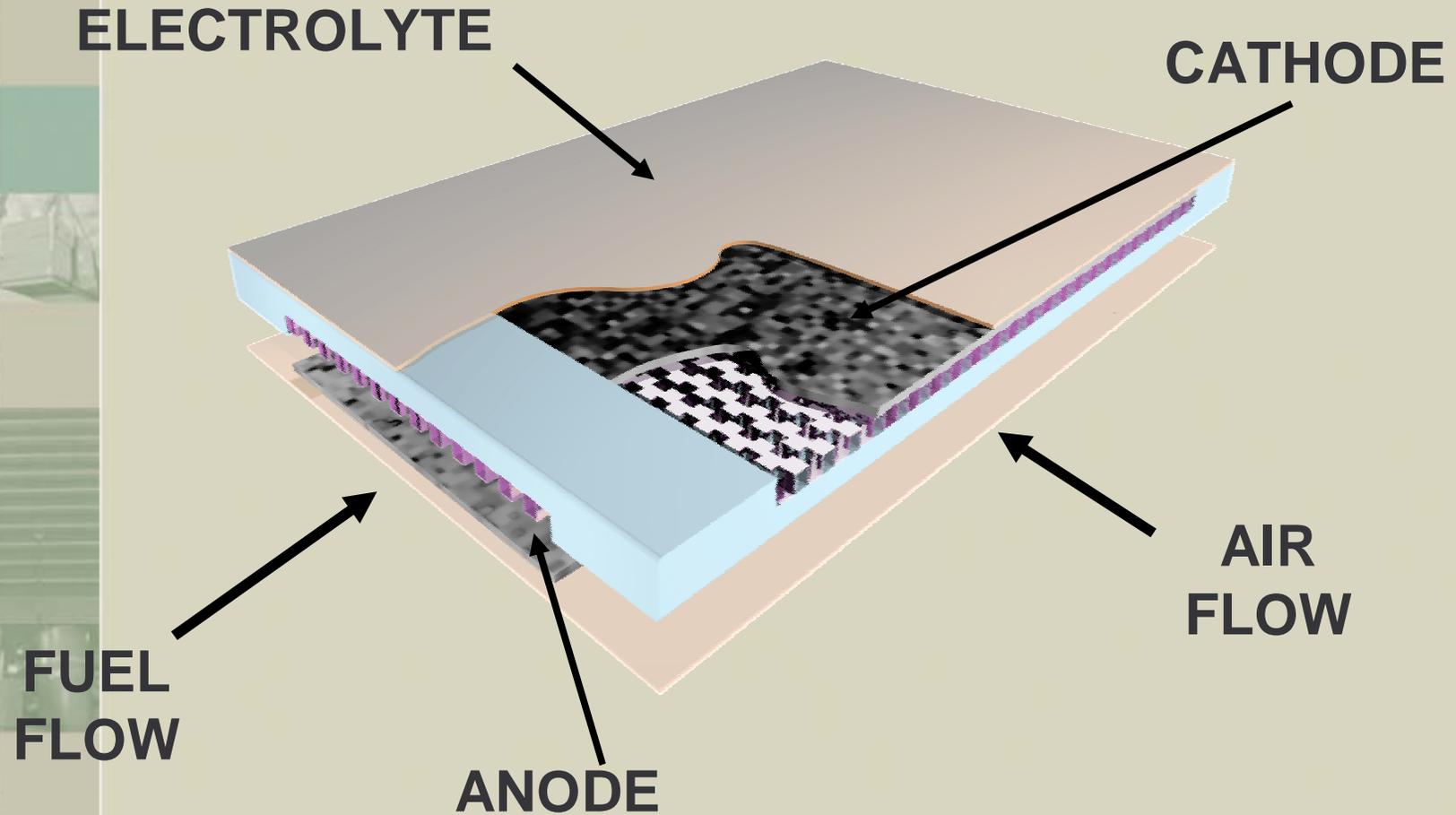
Ni-Al

LiAlO₂

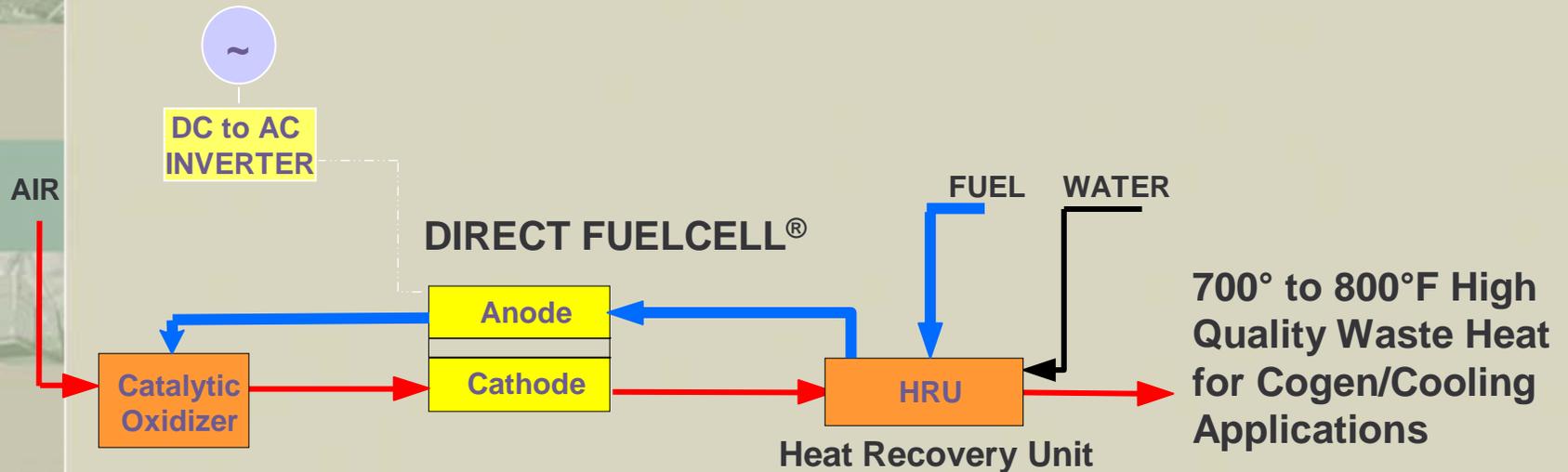
Li doped NiO

DFC Components

Fuel Cell Construction



Simplified DFC[®] System Diagram



Residual 20 - 25% Fuel in Anode Exhaust is Used in Catalytic Oxidizer to Preheat Cathode Air

Cathode Exit Gas is used for Fuel Preheat and Water Vaporization

➡ *No External Reformer*

➡ *Air Blower Only Prime Mover*

FuelCell Energy Products

Small DG



DFC[®] 300



DFC[®] 1500



DFC[®] 3000

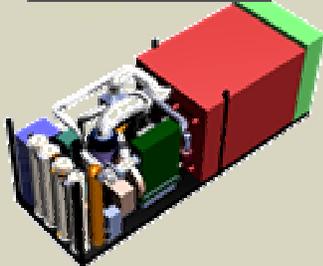
Large DG



DFC/T[®]



Specialty



Marine/Diesel DFC[®]

FuelCell Energy Products

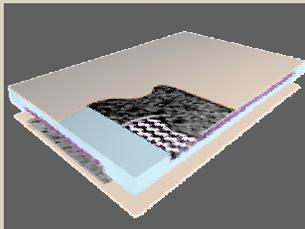
- Building block approach provides scalability and a standardized product to manufacture



Sub-MW Power Plant



Sub-MW Module



Fuel Cell

Distributed Energy Generation



Stack



MW Module



MW Power Plant



Manufacturing the Fuel Cell Module

Established Manufacturing Processes

Tape Casting



Sintering



Lamination



Readily Available Materials

- Stainless Steel
- Nickel
- Ceramic Powders
- Carbonates (common minerals)

Cost Reduction

- Manufacturing Volume
- Elimination of First Costs
- Performance Improvements
- Manufacturing Improvements



Target Customers

■ Institutional

- ▶ Hospitals
- ▶ Universities



■ Commercial

- ▶ Hotels
- ▶ Data Centers
- ▶ Office/Shopping



■ Industrial

- ▶ Waste Water
- ▶ Telecom
- ▶ Food & Beverage
- ▶ Chemical
- ▶ Manufacturing



▶ Utility

- ▶ Grid-support



DFC 300 Power Plant At Rose Valley, OH Coal Mine Methane Site



- U.S. coal mine methane amounts to 300 million CFD (equivalent to 6000 MW CO₂ emissions)
- DFC offers a high efficiency, low emission option

2 MW (DFC 3000) Power Plant Being Installed at Wabash River Gasification Site, Terre Haute, IN



- 50% of U.S. power generated by coal
- High efficiency (>47% HHV), and low NO_x, SO_x, and reduced CO₂ make-up water

FuelCell Energy – Partners & Installations

Marubeni – OEM

Caterpillar – OEM

DCX/MTU – OEM

PPL, Chevron, CMS, Alliance – ESCO

LADWP, DOE, DOD, EPA

Kirin Brewery – CHP, industrial WWT
City of Fukuoka – CHP, municipal WWT
Nippon Metal – CHP, natural gas

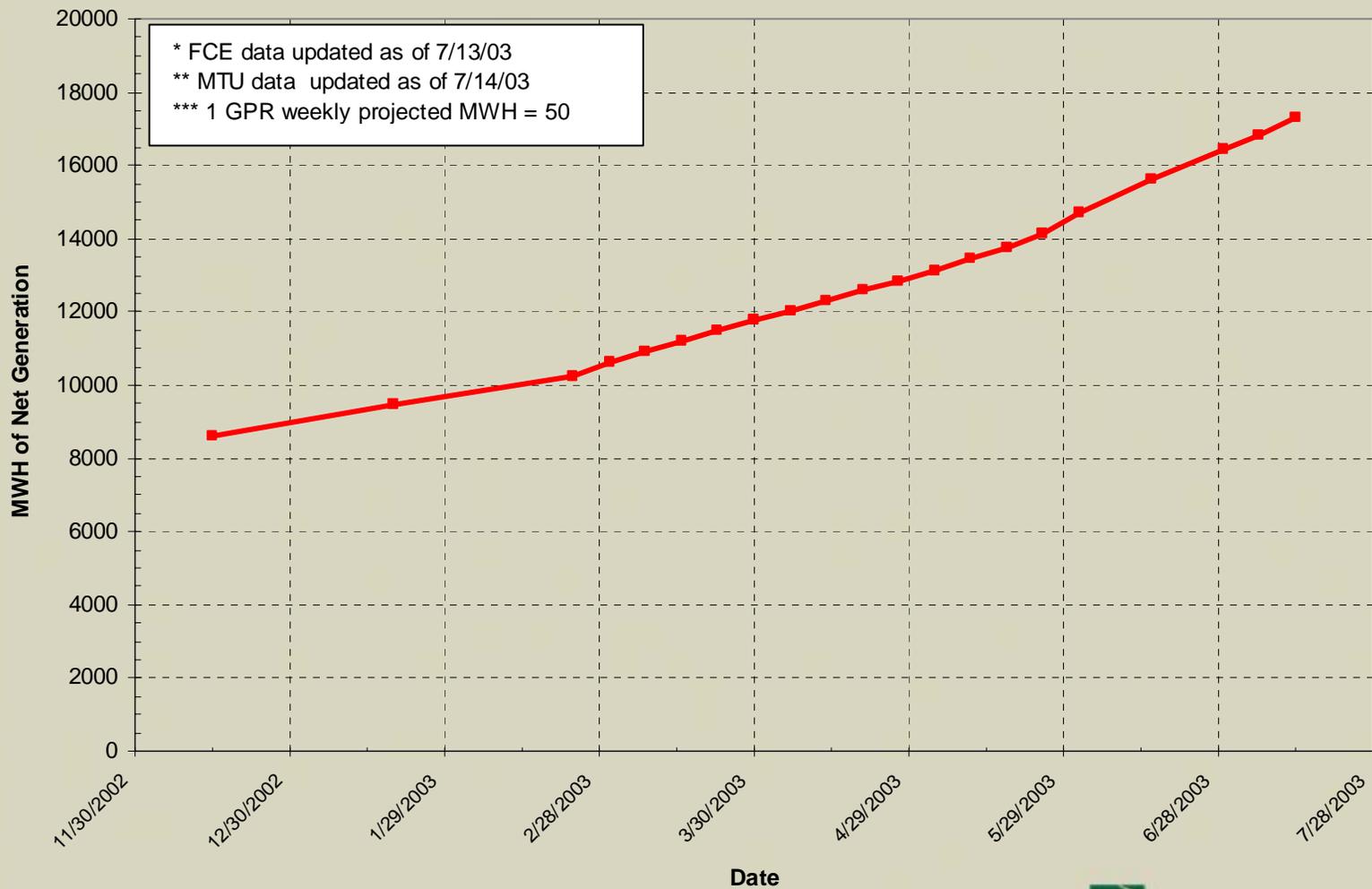
Coast Guard – CHP, barracks
Sheraton (2) – CHP, hotels
Ocean County College – CHP, university
Yale University – CHP, university
Zoot Enterprises (2) – reliability for critical load
Harrisburg Coal Mine – power from coal mine emissions
DFC/T (2) – Vision 21 combined cycle
Clean Coal (2MW) – power from coal-derived syngas
King County (1MW) – CHP, municipal WWT
Mercedes – power for general load
LADWP – power for office headquarters
LADWP – CHP, WWT
Grand Valley State University – CHP, university
Navy – land-based marine diesel application
AMP-Ohio – utility-scale grid support at substation

University of Bielefeld – CHP, hospital
Rhon-Klinikum – CHP, hospital
RWE – CHP, energy park
IZAR – power, ship-builder
Deutsche Telecom – DC backup, telecom
EnBW/Michelin – electricity/steam, manufacturing
IPF Magdeburg – CHP, medical clinic
Gruenstadt Clinic/Pfalzwerke – CHP, medical clinic



Total Net MWH Generation

Total Net MWH Generation (FCE & MTU Combined)



Fuels for Carbonate Fuel Cells

Tested/Demonstrated

- Natural Gas
- Digester Gas
- Propane
- Methanol
- Coal Mine Methane
- Coal-derived Gas
- Diesel

TBD

- Direct Carbon
- (Issues - impurities, cell and stack design, electrochemical performance)

