An Introduction to Fuel Cell Applications for Microgrids and Critical Facilities

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Hosted by
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20 February 2013

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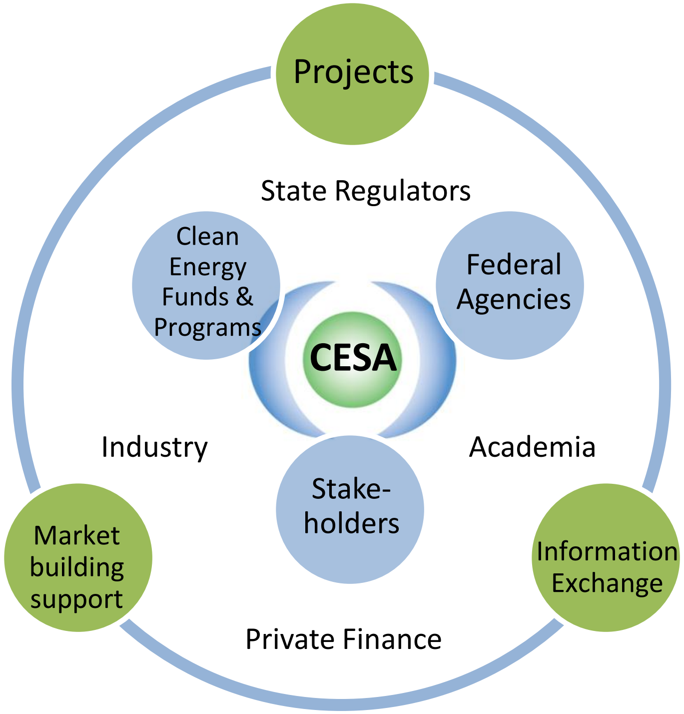
About CESA

Clean Energy States Alliance (CESA) is a national nonprofit organization dedicated to advancing state and local efforts to implement smart clean energy policies, programs, technology innovation, and financing tools to drive increased investment and market making for clean energy technologies.

What We Do

- Multi-state coalition of clean energy programs cooperating and learning from each other, leveraging federal resources
- CESA state members have nearly $6 billion to invest in next 10 years
- Members have supported nearly 130,000 renewable energy projects from 1998-2011 with state-based dollars
- Nonpartisan, experimental, collaborative network
  - Information exchange & analysis
  - Partnership development
  - CESA projects: solar, wind, RPS, fuel cells, energy storage, program evaluation, national database



Northeast Electrochemical Energy Storage Cluster

Network of industry, academic, government, and non-governmental leaders working together to promote the development and deployment of fuel cells and hydrogen fuels. NEESC works to accelerate adoption, deployment, and innovation by providing business resources, networking opportunities, workshops, and other opportunities to drive economic development in this sector.

http://www.neesc.org/

Why Fuel Cells in Microgrids and Critical Facilities?

- Highly efficient and highly reliable
- Require less maintenance than traditional generator sets
- Remote monitoring
- Minimal noise
- Very low emissions
- Certain fuel cell types can be switched on and off relatively quickly without damage

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FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

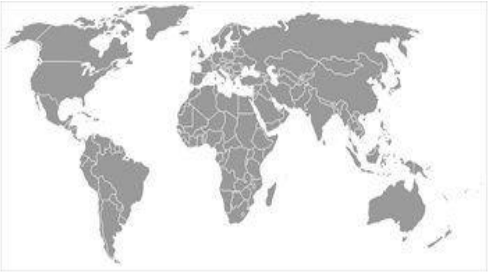
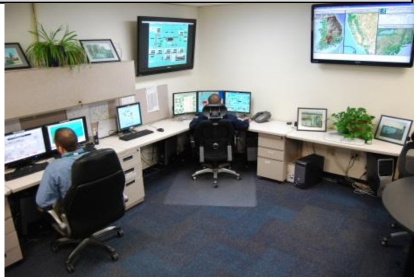
CESA/NEESC Webinar on Fuel Cells

Andrew Skok   Sr. Director, FuelCell Energy

February 20 2013

FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

Integrated Fuel Cell Company

Manufacture	**Sell** (direct & via partners)	**Install**	**Services**
			

Growing Market Presence

300 MW installed and in backlog	Over 80 Direct FuelCell® plants generating power at more than 50 sites globally	Providing: • On-site power • Utility grid support

Delivering Ultra-clean Baseload Distributed Generation Globally

600 kW plant at a food processor

1.4 MW plant at a municipal building

2.4 MW plant owned by an independent power producer

11.2 MW plant – World's largest operating fuel cell park

Comparison to Alternate Solutions

● Good Solution ◐ Possible or Partial Solution ○ Poor Solution

	Capacity Factor	24/7 Power	Peaking Power	Central Generation	DG or On-Site Power	SOX, NOX Particulate Matter	CO2 Reduction	Avoid Siting, NIMBY Issues
Conventional Combustion	Up to 95%	●	◐	●	◐	○	○	○
Wind	20-35%	○	○	●	◐	●	●	○
Solar	15-25%	○	◐	○	●	●	●	●
Fuel Cells	Up to 95%	●	○	●	●	●	●	●

Fuel cells offer an economically compelling balance of attributes

Fuel Cell Benefits

- Ultra-Clean, Efficient and Reliable Power
  - **Continuous and secure baseload power**
  - **Complements intermittent wind and solar**
  - **Does not require transmission grid**
- Near-zero NOx, SOx and particulate matter emissions
  - **Allows siting in congested/urban areas**
- Higher electrical efficiency than competing technologies
  - **47% to 70% electrical efficiency, up to 90% with combined heat & power (CHP)**
  - **Efficiency drives economics**
- Distributed generation - power where needed
  - **Enables smart grid**

1.4 MW power plant

2.8 MW power plant

11.2 MW power plant

Products Based on Cell Stack Building Block

Cell Package and Stack

Single-Stack Module

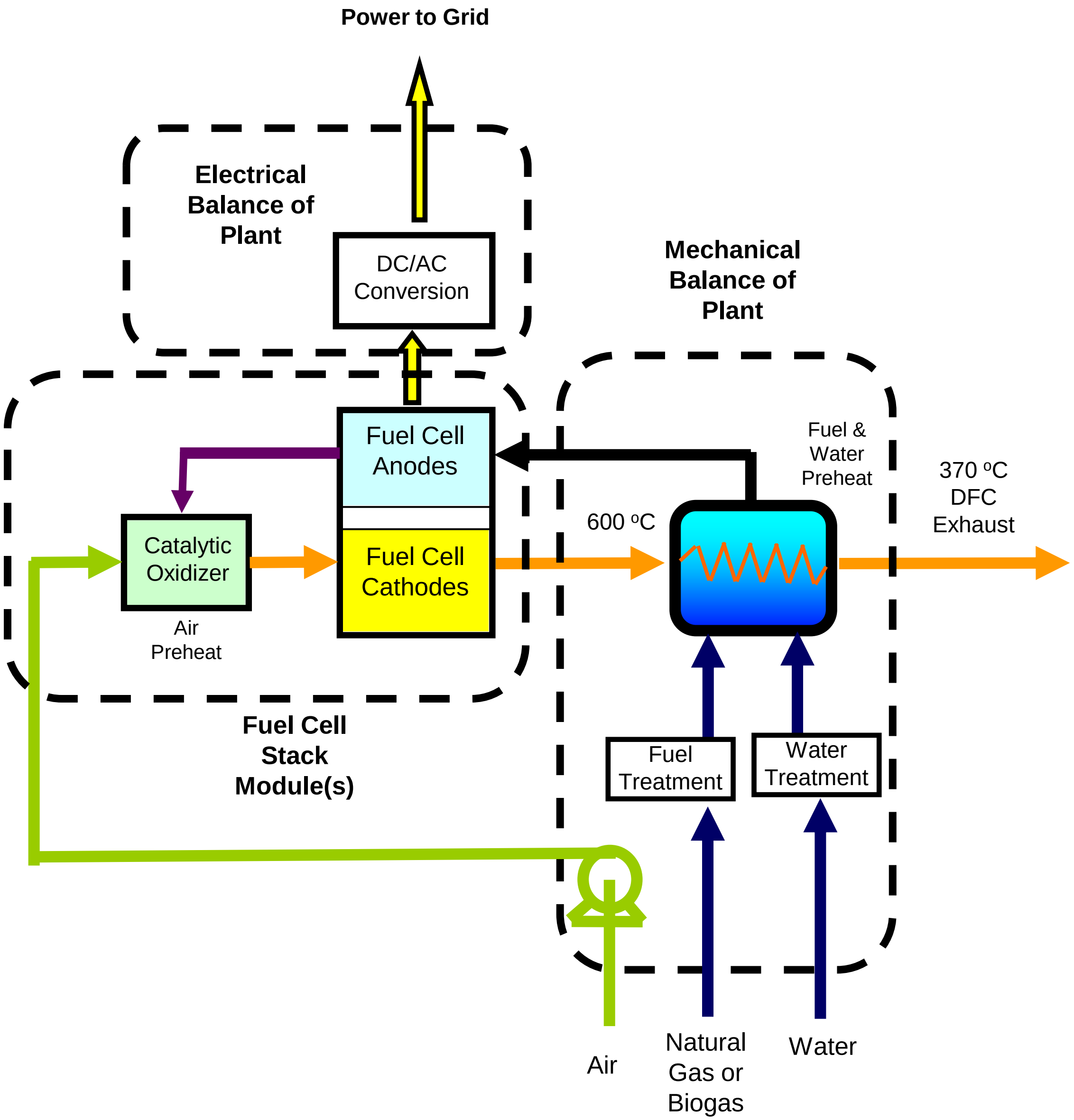
Four-Stack Module

DFC300
Single Module Powerplant
300 kW

DFC1500
One 4-Stack Module
1.4 MW

DFC3000
Two 4-Stack Modules
2.8 MW

DFC System



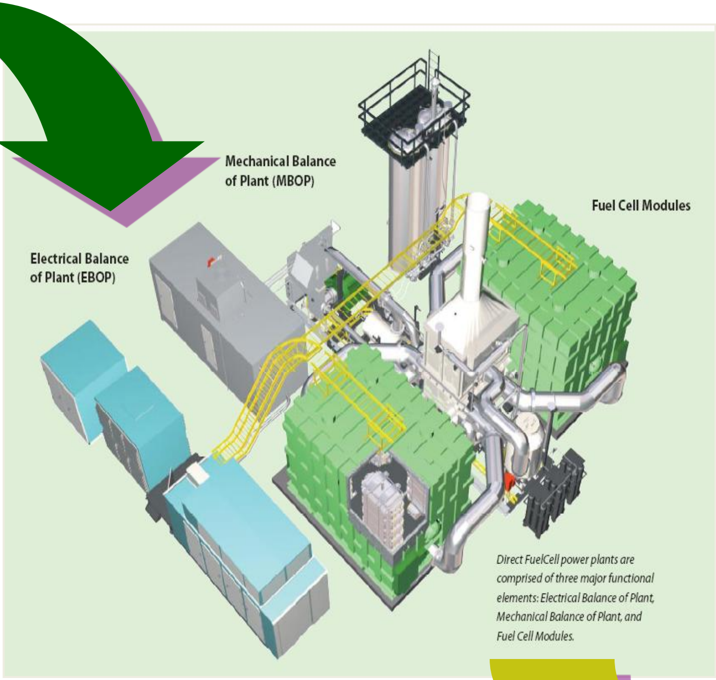
- Fuel and Water are treated to remove contaminants (e.g. sulfur), mixed, heated to stack temperature and sent to anodes
- Fuel and water react in anode chambers to produce hydrogen
- Anodes consume 70% of hydrogen in power generation
- Residual 30% hydrogen used in catalytic oxidizer to pre-heat air
- Heated air is cathode gas
- Cathode exit gas is 600 – 650 C, cooled to 370 C after fuel/water preheat
- 370 C exhaust used for cogeneration heat recovery

Application Diversity

Diversity of Fuels plus High Efficiency – High Sustainability

FUEL RESOURCES

- **NATURAL GAS**
- **METHANOL**
- **ETHANOL**
- **PROCESS METHANE**
- **BIOGAS**
- **COAL GAS**



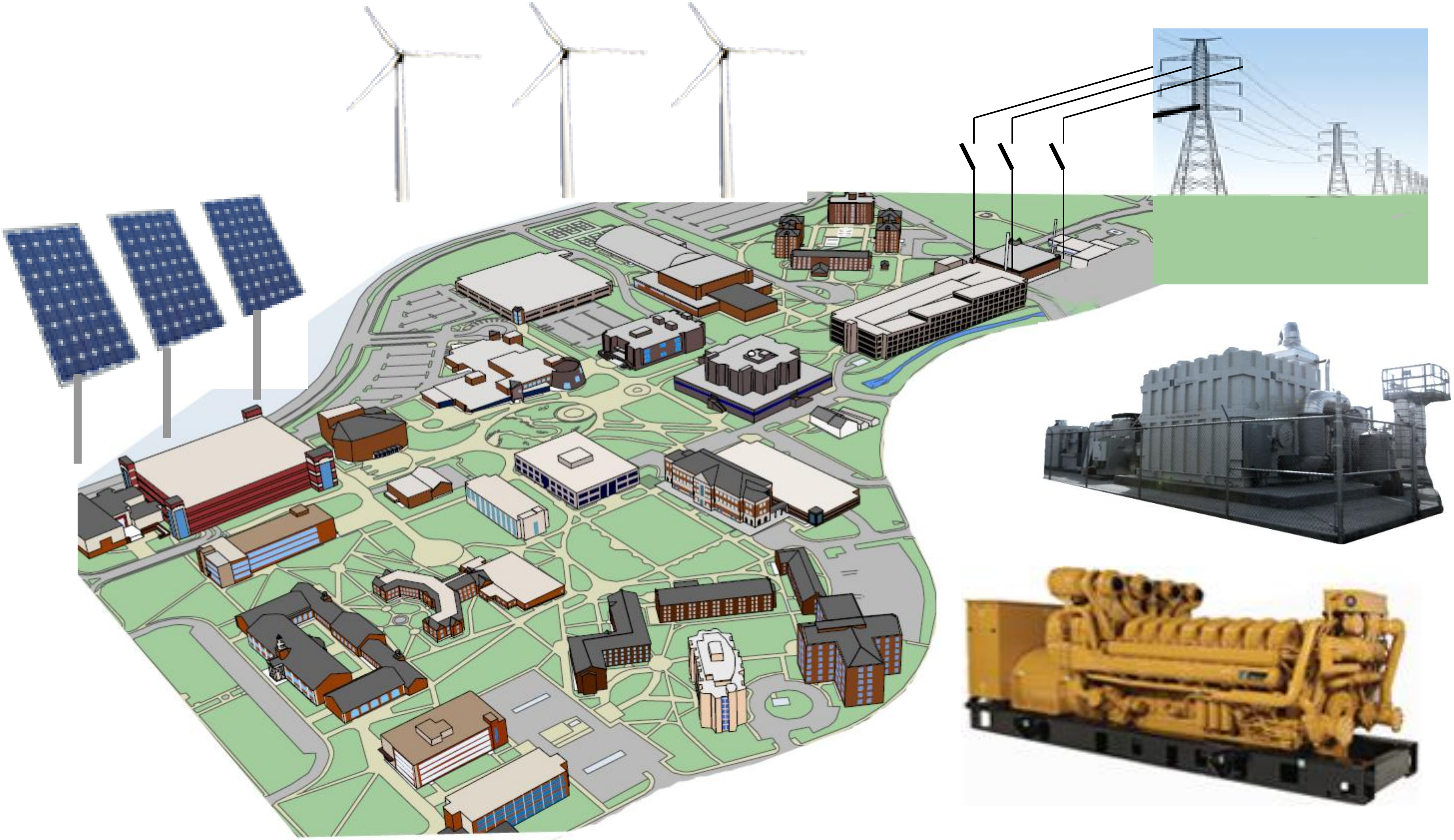
Direct FuelCell power plants are comprised of three major functional elements: Electrical Balance of Plant, Mechanical Balance of Plant, and Fuel Cell Modules.

INTEGRATED SYSTEMS IMPROVE EFFICIENCY

- **DFC – (47%)**
- **DFC – CHP (60-80%)**
- **DFC – ERG (55-70%)**
- **DFC/T – (60-70%)**
- **DFC H2 (50-60%)**

Micro Grid Defined

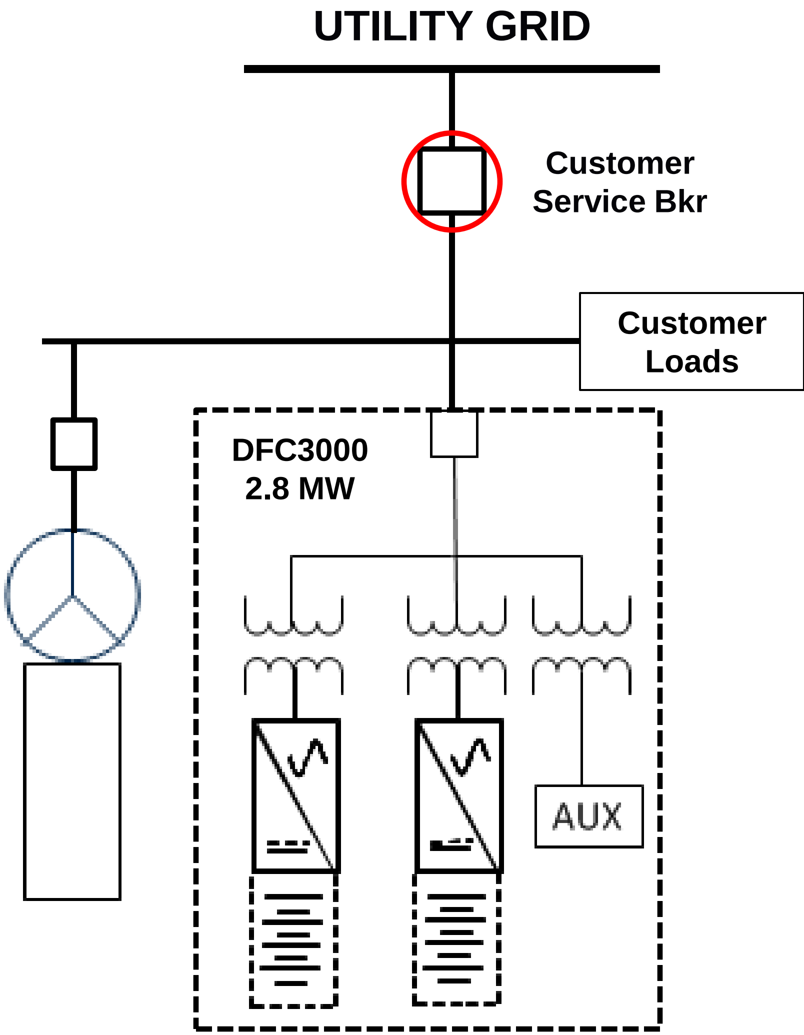
Micro-grid: **A collection of loads separated from the utility grid at one point and powered by local generation sources.**



Micro-Grid Base Load Mode

Typical Sequence of Operation:

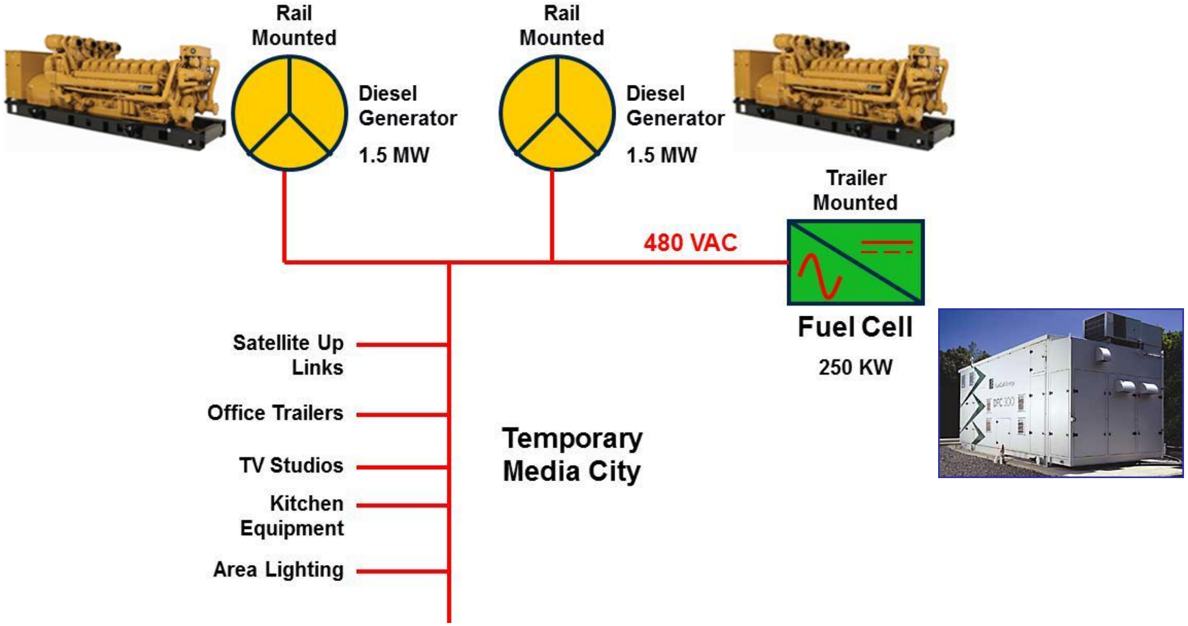
- t0: Grid Outage
- t1: DFC transitions to Stand-Alone Mode, Facility goes dark
- t2: Genset(s) starts, Service Breaker Opens, Sends micro-grid signal to DFC
- t3: Genset connects to bus at rated voltage and frequency.
- t4: DFC syncs with genset and connects to bus with wider V&F relay settings and active anti-islanding disabled.
- t5: DFC ramps to rated power in 5 minutes.



FCE’s First Micro-Grid

2004 Democratic National Convention – Boston

- Generated valuable lessons learned
- Directed future product development activities



Rail Mounted

Diesel Generator 1.5 MW

Rail Mounted

Diesel Generator 1.5 MW

Trailer Mounted

480 VAC

Fuel Cell 250 KW

Satellite Up Links

Office Trailers

TV Studios

Kitchen Equipment

Area Lighting

Temporary Media City

Micro Grid Experience

FCE is actively implementing micro-grid mode at several sites.

- Parallel operation with other generators when utility service unavailable
- Customer facilities, behind-the-meter applications
- Interruptible and Seamless Applications

Recent Micro grid Implementations:

Central CT State University

- Gensets & 1.4MW fuel cell

San Jose Water Treatment Plant

- Gensets & 1.4MW fuel cell

Santa Rita County Jail

- DOE Smart Grid Demonstration
- Facility Static Switch Disconnect
- 1MW early generation Fuel Cell
- Gensets,1mw solar,
- 2MW energy storage

Case Study: Ultra-Clean Power

CENTRAL CONNECTICUT STATE UNIVERSITY

ULTRA-CLEAN BASELOAD DISTRIBUTED GENERATION FOR A UNIVERSITY.

BENEFITS

The campus and University System benefit with favorable economics that generate an estimated **$100,000/year in savings,** reliable on-site power that supports the University micro-grid strategy, and environmentally friendly power generation that advances the sustainability goals of the University.

SOLUTION

FuelCell Energy, Inc. installed an **ultra-clean, efficient** and **reliable** 1.4 megawatt Direct FuelCell® power plant that meets approximately 35 percent of the campus power needs. On-site power generation supports the University **micro-grid**, which ensures **continuous power availability** to critical campus buildings in the event of a disruption of the electric grid.

"This fuel cell power plant represents a significant step towards CCSU achieving its aggressive goals for greenhouse gas reduction and improving energy efficiency," said Jack Miller, President, Central Connecticut State University, whose Sustainability Initiative was responsible, in part, for the University's selection as an "exemplary Green institution" by the Princeton Review. "By providing both electricity and steam in such a clean and efficient manner, the fuel cell plant decreases our carbon emissions."

FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

Advanced Technology Programs

Hydrogen production & compression

- Produce hydrogen, electricity and heat
- Markets: vehicle fueling & industrial gas applications
- Enables hydrogen infrastructure

Renewable biogas fueled DFC300-H2 in CA providing hydrogen for vehicle fueling under DOE demonstration program

High electrical efficiency plants

- Hybrid DFC systems - Electrical efficiency 55%-70%

High efficiency DFC-ERG in Toronto, Canada

Efficient and cost effective CO2 separation

- Use DFC plants for carbon capture
- Direct the flue gas from coal-fired power plants into the fuel cell for CO2 separation

Carbon capture research funded by US DOE and US EPA

Leveraging Core Technology to Expand Market Opportunities

Key Advantages of DFC

- High electrical efficiency
- Low emissions
- High quality waste heat for co-generation
  - Steam
  - Hot water
  - Absorption Chilling
- Low Noise
- Baseload clean power
- Strong Micro Grid attributes

Be Clean.
Be Green.
Be Safe.

Fuel cell energy is ultra-clean. That means we give off negligible NOx and SOx emissions, and fit neatly and quietly in a variety of locations.

Fuel cells are also green. They run on biofuels – gases from wastewater treatment, food processing, and landfills – in addition to natural gas. Plus they're efficient. They generate more electricity per unit of fuel than any other energy source, and make efficient use of residual heat.

Most important, stationary fuel cells are the only 24/7 ultra-clean distributed power source available. That's because fuel cells do not depend on wind or sunshine, and reduce your reliance on the power grid. You can build one, literally, anywhere and depend on it around the clock.

Protect your facility from power interruptions, and deal a serious blow to carbon emissions.

Fuel cells exceed all 2007 California Air Resources Board (CARB) requirements.

DFC1500MA 1.2 MW Fuel Cell Power System

FuelCell Energy
World Leader in Ultra-Clean Power

Thank You

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Benefits of Fuel Cells in Microgrids

February 20, 2013

Joel M. Rinebold
Connecticut Center for
Advanced Technology, Inc.

Microgrid Criteria

- Reduce impact of outages on critical facilities
- Reduce economic output losses
- Reduce emissions
- Reduce costs
- Increase high efficiency and renewable generation
- Increase economic development and job creation

Fuel Cell Criteria

- High reliability
- Base load operation
- High capacity factor
- Use of domestic and renewable fuels
- Clean operation
- Made in U.S.

Fuel Cell Microgrid Build-out

- Power to customer(s) and islanded grid
- Critical facilities selected by community
- Transfer trip scheme
- Automated demand response
- Clean base load operation
- “Green Jobs”

Fuel Cell Microgrid Plan

- Identify Critical community facilities
- Characterize area load requirements
- Analyze power grid and transfer trip points
- Interconnect with automated demand response
- Operate with islanding for backup

Fuel Cell Microgrid Targets

Critical Facilities

- Computers, Servers, and other IT Infrastructure
- Telecomunications
- HVAC
- Lighting
- Machinery / Production
- Fueling
- Water / Waste Management

Businesses and business parks with significant employment presence

Controlled Islanding

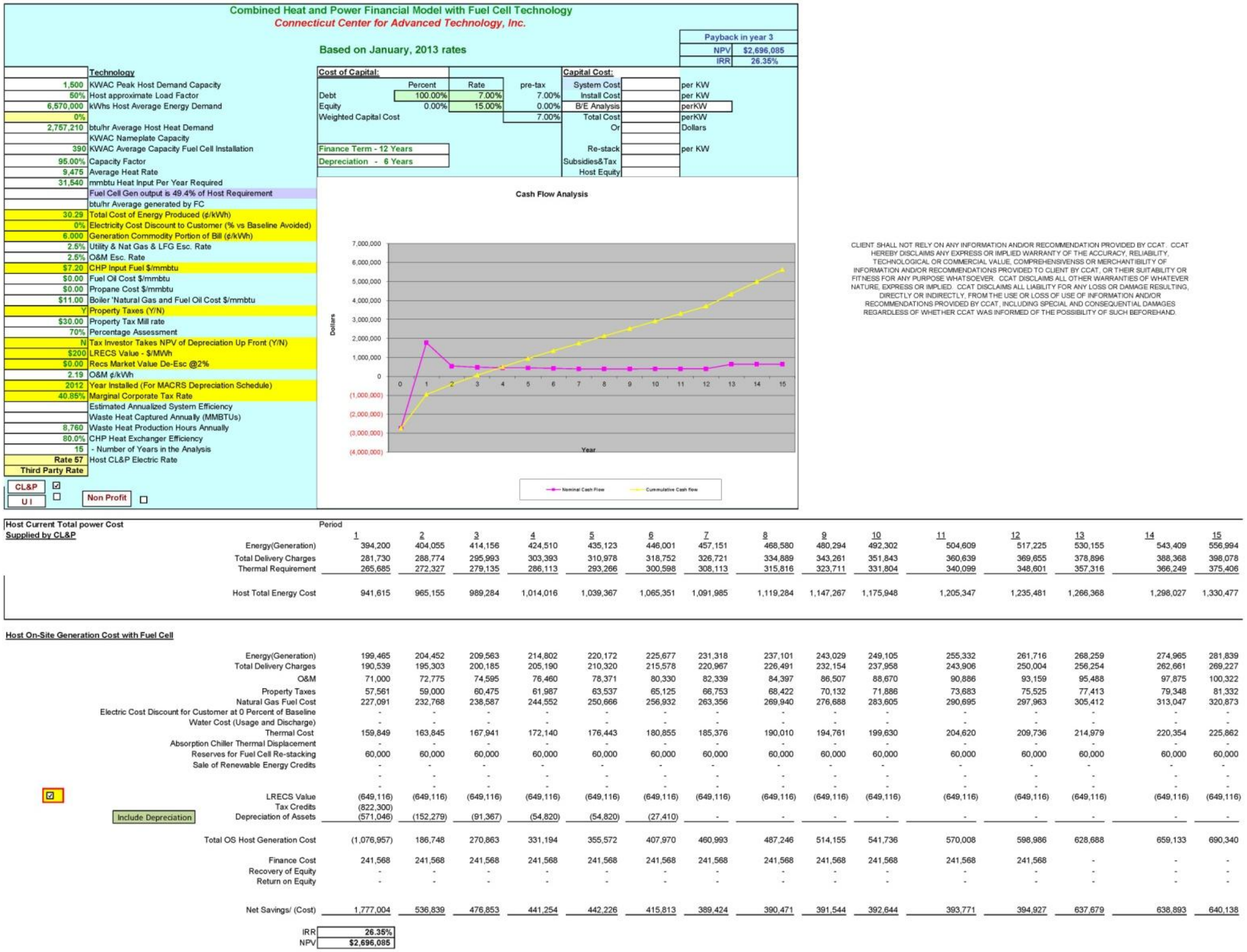
- Capability to isolate a portion of the grid
- Protects line crews
- Employs vertical comprehensive planning
- Enables utility to better serve its customers

Economics/Benefits

Resource Benefits

- Improved reliability for Critical facilities
- High efficiency generation and renewable technology
- Reduced costs from electric service interruptions
- Job creation and economic development
- Community support
- Improved environmental performance
- Improved confidence
- Use of state businesses for manufacture and build out
- Executes energy, environmental, and economic policy

Business Analysis



Combined Heat and Power Financial Model with Fuel Cell Technology

Connecticut Center for Advanced Technology, Inc.

Based on January, 2013 rates

Payback in year 3	
NPV	$2,696,085
IRR	26.35%

	Technology
1,500	KWAC Peak Host Demand Capacity
50%	Host approximate Load Factor
6,570,000	kWhs Host Average Energy Demand
0%	
2,757,210	btu/hr Average Host Heat Demand
	KWAC Nameplate Capacity
390	KWAC Average Capacity Fuel Cell Installation
95.00%	Capacity Factor
9,475	Average Heat Rate
31,540	mmbtu Heat Input Per Year Required
	Fuel Cell Gen output is 49.4% of Host Requirement
	btu/hr Average generated by FC
30.29	Total Cost of Energy Produced (¢/kWh)
0%	Electricity Cost Discount to Customer (% vs Baseline Avoided)
6.000	Generation Commodity Portion of Bill (¢/kWh)
2.5%	Utility & Nat Gas & LFG Esc. Rate
2.5%	O&M Esc. Rate
$7.20	CHP Input Fuel $/mmbtu
$0.00	Fuel Oil Cost $/mmbtu
$0.00	Propane Cost $/mmbtu
$11.00	Boiler 'Natural Gas and Fuel Oil Cost $/mmbtu
Y	Property Taxes (Y/N)
$30.00	Property Tax Mill rate
70%	Percentage Assessment
N	Tax Investor Takes NPV of Depreciation Up Front (Y/N)
$200	LRECS Value - $/MWh
$0.00	Recs Market Value De-Esc @2%
2.19	O&M ¢/kWh
2012	Year Installed (For MACRS Depreciation Schedule)
40.85%	Marginal Corporate Tax Rate
	Estimated Annualized System Efficiency
	Waste Heat Captured Annually (MMBTUs)
8,760	Waste Heat Production Hours Annually
80.0%	CHP Heat Exchanger Efficiency
15	- Number of Years in the Analysis
Rate 57	Host CL&P Electric Rate
Third Party Rate	

CL&P ☑
U I ☐
Non Profit ☐

Cost of Capital:	Percent	Rate	pre-tax
Debt	100.00%	7.00%	7.00%
Equity	0.00%	15.00%	0.00%
Weighted Capital Cost			7.00%

Finance Term - 12 Years

Depreciation - 6 Years

Capital Cost:		
System Cost		per KW
Install Cost		per KW
B/E Analysis		perKW
Total Cost		perKW
Or		Dollars
Re-stack		per KW
Subsidies&Tax		
Host Equity		

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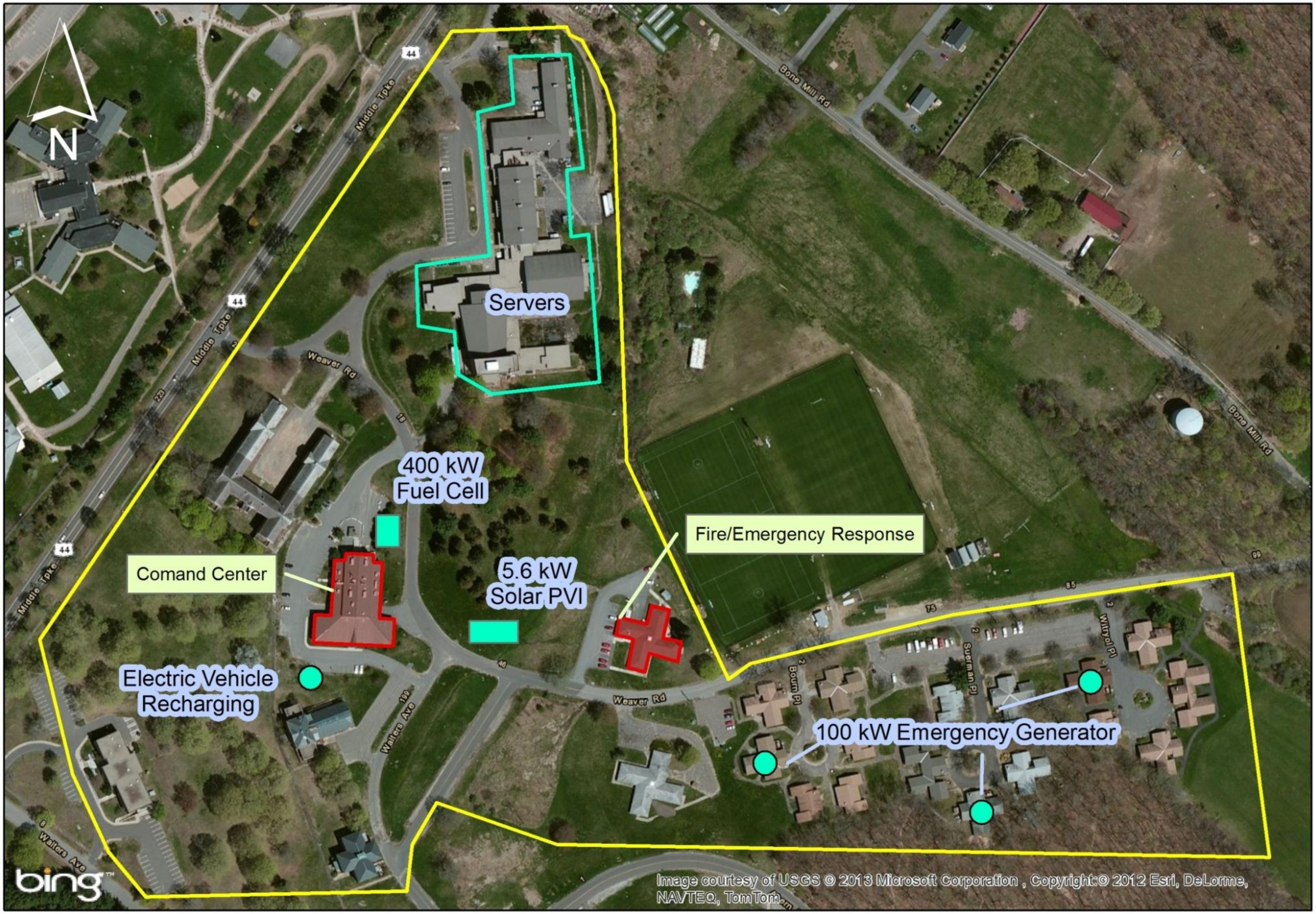
Host Current Total power Cost	Period														
Supplied by CL&P	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Energy(Generation)	394,200	404,055	414,156	424,510	435,123	446,001	457,151	468,580	480,294	492,302	504,609	517,225	530,155	543,409	556,994
Total Delivery Charges	281,730	288,774	295,993	303,393	310,978	318,752	326,721	334,889	343,261	351,843	360,639	369,655	378,896	388,368	398,078
Thermal Requirement	265,685	272,327	279,135	286,113	293,266	300,598	308,113	315,816	323,711	331,804	340,099	348,601	357,316	366,249	375,406
Host Total Energy Cost	941,615	965,155	989,284	1,014,016	1,039,367	1,065,351	1,091,985	1,119,284	1,147,267	1,175,948	1,205,347	1,235,481	1,266,368	1,298,027	1,330,477

Host On-Site Generation Cost with Fuel Cell	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Energy(Generation)	199,465	204,452	209,563	214,802	220,172	225,677	231,318	237,101	243,029	249,105	255,332	261,716	268,259	274,965	281,839
Total Delivery Charges	190,539	195,303	200,185	205,190	210,320	215,578	220,967	226,491	232,154	237,958	243,906	250,004	256,254	262,661	269,227
O&M	71,000	72,775	74,595	76,460	78,371	80,330	82,339	84,397	86,507	88,670	90,886	93,159	95,488	97,875	100,322
Property Taxes	57,561	59,000	60,475	61,987	63,537	65,125	66,753	68,422	70,132	71,886	73,683	75,525	77,413	79,348	81,332
Natural Gas Fuel Cost	227,091	232,768	238,587	244,552	250,666	256,932	263,356	269,940	276,688	283,605	290,695	297,963	305,412	313,047	320,873
Electric Cost Discount for Customer at 0 Percent of Baseline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Cost (Usage and Discharge)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thermal Cost	159,849	163,845	167,941	172,140	176,443	180,855	185,376	190,010	194,761	199,630	204,620	209,736	214,979	220,354	225,862
Absorption Chiller Thermal Displacement	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reserves for Fuel Cell Re-stacking	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
Sale of Renewable Energy Credits	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
☑	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LRECS Value	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)	(649,116)
Tax Credits	(822,300)														
Include Depreciation — Depreciation of Assets	(571,046)	(152,279)	(91,367)	(54,820)	(54,820)	(27,410)	-	-	-	-	-	-	-	-	-
Total OS Host Generation Cost	(1,076,957)	186,748	270,863	331,194	355,572	407,970	460,993	487,246	514,155	541,736	570,008	598,986	628,688	659,133	690,340
Finance Cost	241,568	241,568	241,568	241,568	241,568	241,568	241,568	241,568	241,568	241,568	241,568	241,568	-	-	-
Recovery of Equity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Return on Equity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net Savings/ (Cost)	1,777,004	536,839	476,853	441,254	442,226	415,813	389,424	390,471	391,544	392,644	393,771	394,927	637,679	638,893	640,138

IRR	26.35%
NPV	$2,696,085

UConn Microgrid

Connecticut Center for Advanced Technology, Inc.



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2/19/2013

Summary

- Increased power reliability and security
- Increased public safety
- Improved business competitiveness
- Increased manufacturing and employment
- Improved vertical integration of grid assets
- Catalyzed development of smart grid
- Energy, environmental, and economic policy

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State of Connecticut
Microgrid Grant and Loan Pilot Program

Connecticut Department of
ENERGY &
ENVIRONMENTAL
PROTECTION