RESILIENT POWER

A Project of Clean Energy Group

Fuel Cells for Wastewater Treatment Plants

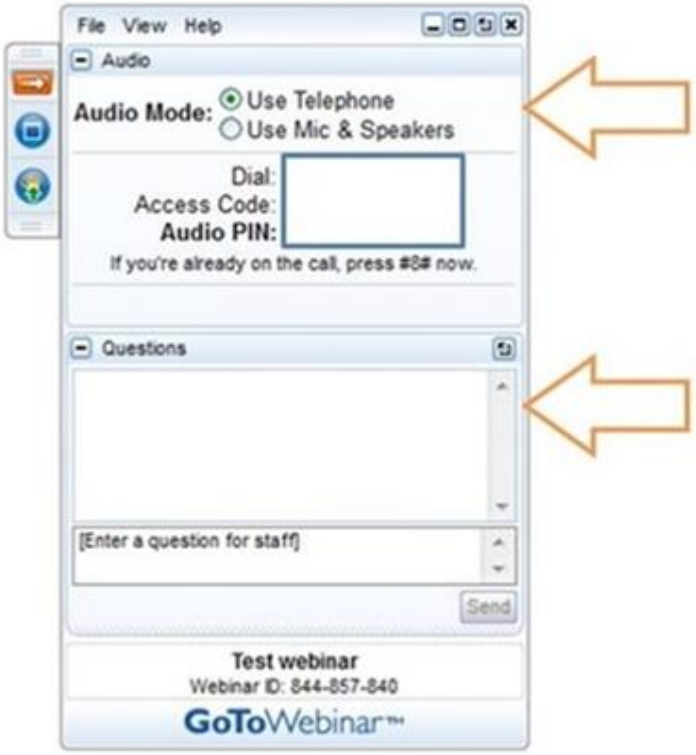
Wednesday, September 9, 2015

Seth Mullendore
Project Manager
Clean Energy Group

CleanEnergyGroup
Innovation in Finance, Technology & Policy

Northeast Electrochemical energy storage Cluster

Housekeeping



All participants are in "Listen-Only" mode. Select "Use Mic & Speakers" to avoid toll charges and use your computer's VOIP capabilities. Or select "Use Telephone" and enter your PIN onto your phone key pad.

Submit your questions at any time by typing in the Question Box and hitting Send.

This webinar is being recorded.

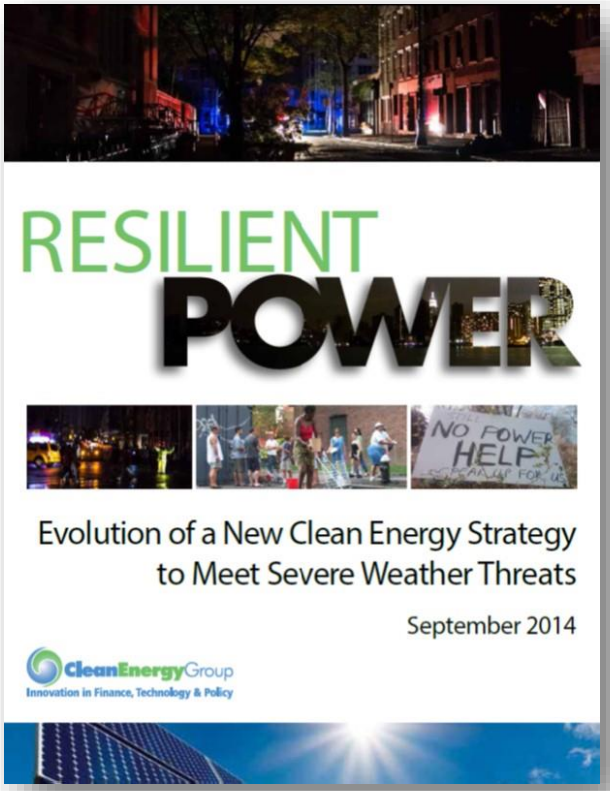
You will find a recording of this webinar, as well as previous Resilient Power Project webinars, online at:

www.cleanegroup.org/ceg-projects/resilient-power-project/webinars/

and at

vimeo.com/channels/resilientpower

Who We Are



www.cleanegroup.org

CleanEnergyGroup
Innovation in Finance, Technology & Policy

Meridian Institute
Connecting People to Solve Problems

CleanEnergy States Alliance

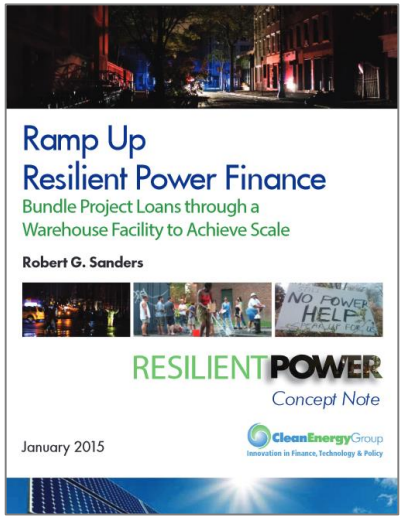
THE JPB FOUNDATION

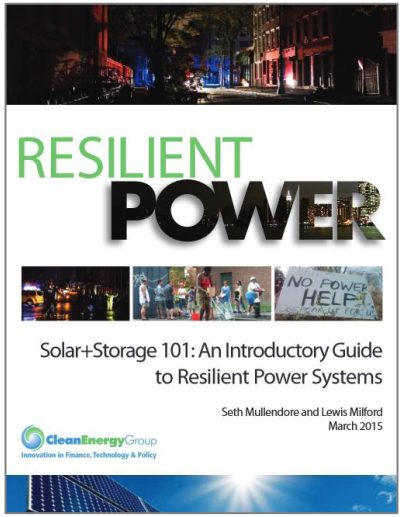
THE KRESGE FOUNDATION

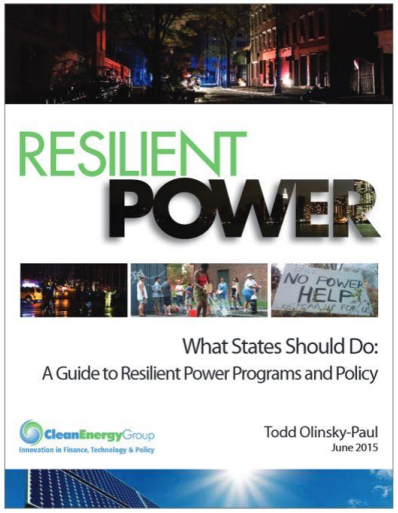
SURDNA FOUNDATION
Fostering sustainable communities in the United States

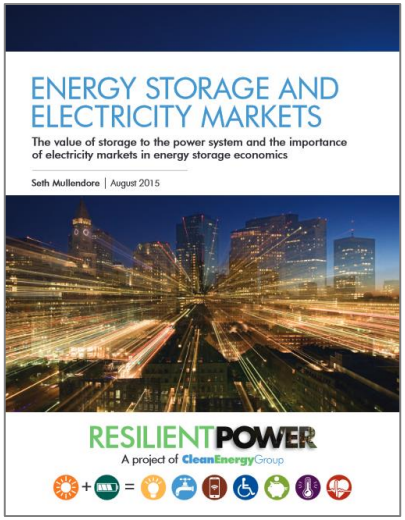
Resilient Power Project

- Increase public/private investment in clean, resilient power systems
- Engage city officials to develop resilient power policies/programs
- Protect low-income and vulnerable communities
- Focus on affordable housing and critical public facilities
- Advocate for state and federal supportive policies and programs
- Technical assistance for pre-development costs to help agencies/project developers get deals done
- See www.resilient-power.org for reports, newsletters, webinar recordings









Northeast Electrochemical Energy Storage Cluster (NEESC)

NEESC is a network of industry, academic, government and non-governmental leaders working together to help businesses provide energy storage solutions.

Northeast Electrochemical energy storage Cluster

www.neesc.org

Today's Guest Speakers

- **Ken Wicker**, Director – Business Development, Fuel Cell Energy, Inc.
- **Ernest P. Marquez, Jr**, Principal Engineer, City of Riverside, CA
- **Jim Mullins**, Senior Engineer, Orange County Sanitation District

FuelCell Energy

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ORANGE COUNTY SANITATION DISTRICT

PROTECTING THE ENVIRONMENT

CITY OF RIVERSIDE

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Fuel Cells for Wastewater Treatment Plants



Clean Energy Group and
Northeast Electrochemical Energy Storage Cluster
September 9, 2015

Ultra-Clean | Efficient | Reliable Power

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Agenda

- The Opportunity
- FuelCell Energy's Technology
- Case Studies & Lessons Learned
- Renewable Hydrogen
- Economic Opportunities

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The Opportunity

FuelCell Energy's multi-MW carbonate fuel cells are well-suited for large wastewater treatment plants that can utilize their biogas for on-site cogeneration purposes.

- Wastewater treatment plants can generate digester gas with approximately 60% methane, which is a perfect source of fuel for FCE's molten carbonate fuel cells.
- Biogas is considered a renewable resource and can garnish all the associated benefits from running a treatment plant on renewables.
- Wastewater treatment plants operate 24/7 and so do fuel cells, which is a good fit between energy producer and energy consumer.

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Integrated Fuel Cell Company

Research & Development

Design megawatt–class distributed power generation solutions

- ***Global fuel cell platform***
- ***Robust intellectual property portfolio***
- ***Developing hybrid applications of existing technology for new markets***

Sales, Manufacture & Project Execution

Project development
- ***Direct sales***

Global manufacturing profile
- ***North America***
- ***Asia via partner***
- ***Europe***

Engineering, Procurement and Construction
- ***Project Financing***

Services

Operate & Maintain power plants

- ***Over 100 DFC® plants operating at more than 50 sites in 9 countries***
- ***>3 billion kWh ultra-clean power produced***
- ***> 300 MW installed/backlog***

Providing turn-key distributed power generation solutions

NASDAQ: FCEL

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Scalable Solutions

Global platform – scale enhances economics

Individual fuel cell
&
350 kW fuel cell stack

Completed module
1.4 megawatts

Four-Stack Module
1.4 megawatts

59MW fuel cell park
- *Utilizes 21 DFC3000 plants*

2.8 MW DFC3000®
- *Utilizes two modules*
- *Adequate to power 2,800 homes*

1.4 MW DFC1500®
- *Utilizes one module*
- *Adequate to power 1,400 homes*

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Why Fuel Cells?

- Clean, Quiet & Efficient
- Energy Cost Savings
- Financeable, Low-Risk
- Reliable & Enhanced Resiliency

Power Source	Efficiency (%LHV)	NOx (lb/MWh)	SOx (lb/MWh)	PM^{10} (lb/MWh)	CO_2 (lb/MWh)
Average U.S. Grid	33%	3.43	7.9	0.19	1,408
Average U.S. Fossil Fuel Plant	36%	5.06	11.6	0.27	2,031
DFC® Fuel Cell on Nat Gas	**47%**	**0.01**	**0.0001**	**0.00002**	**940**
DFC® Fuel Cell on Nat Gas (CHP)	**80%**	**0.006**	**0.00006**	**0.00001**	**550**
DFC® Fuel Cell on Biogas (CHP)	**80%**	**0.006**	**0.00006**	**0.00001**	**0**

Source: The Regulatory Assistance Project report to NREL, October 15, 2002

Hartford Hospital, 1.4 MW

Cal State East Bay, 1.4 MW

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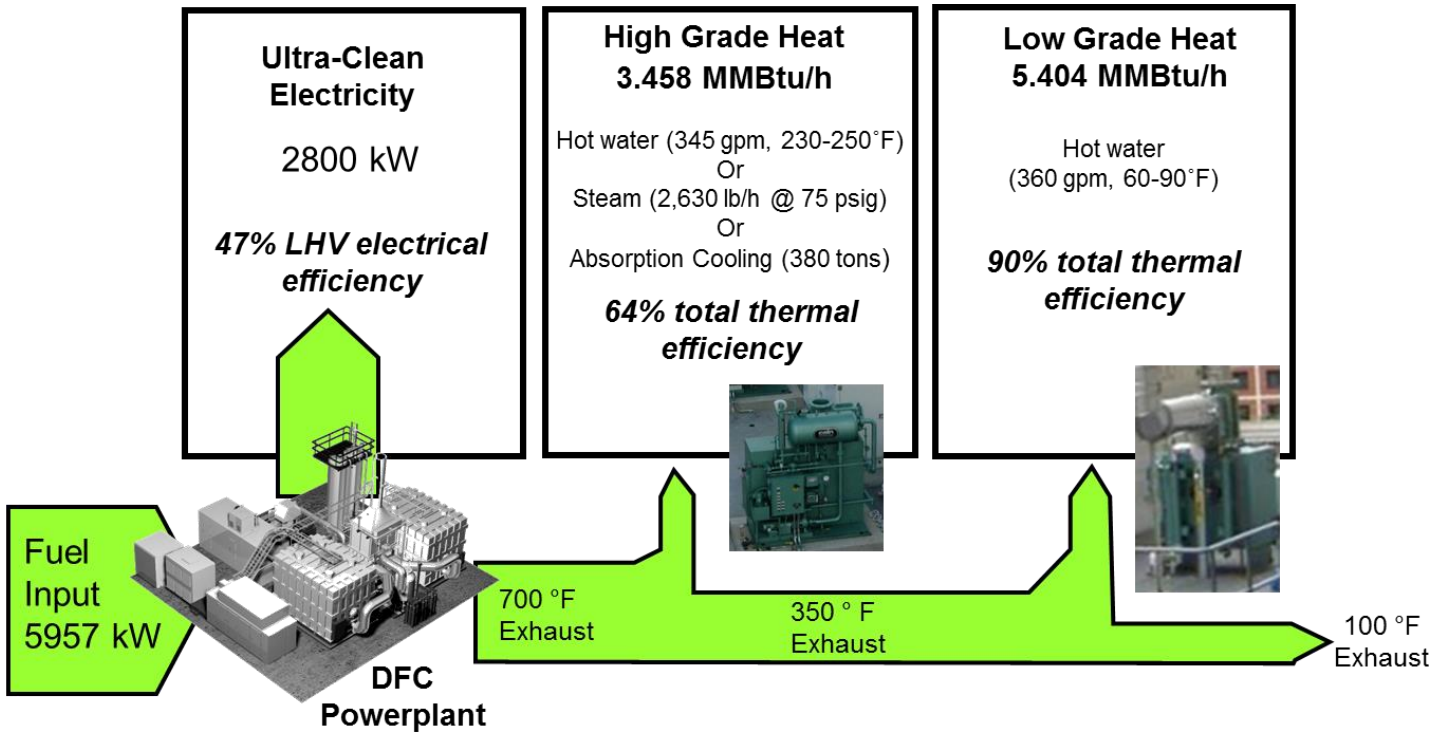
FuelCell Energy CHP Applications



300 kW Hot Water CHP for Onion Waste digester in California

1.4 MW Steam CHP for campus energy system at University in CT

2.8 MW Hot Water CHP Waste Water Digester Plant in California

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Application Requirements 2.8MW

- Space requirement: 60 ft x 75 ft (additional 30 ft for maintenance)
- Electric generation ~22 million kWh per year
- Waste heat generation ~ 4.4 MM/Btuh
- Heat load for hot water, steam, and/or absorption cooling.

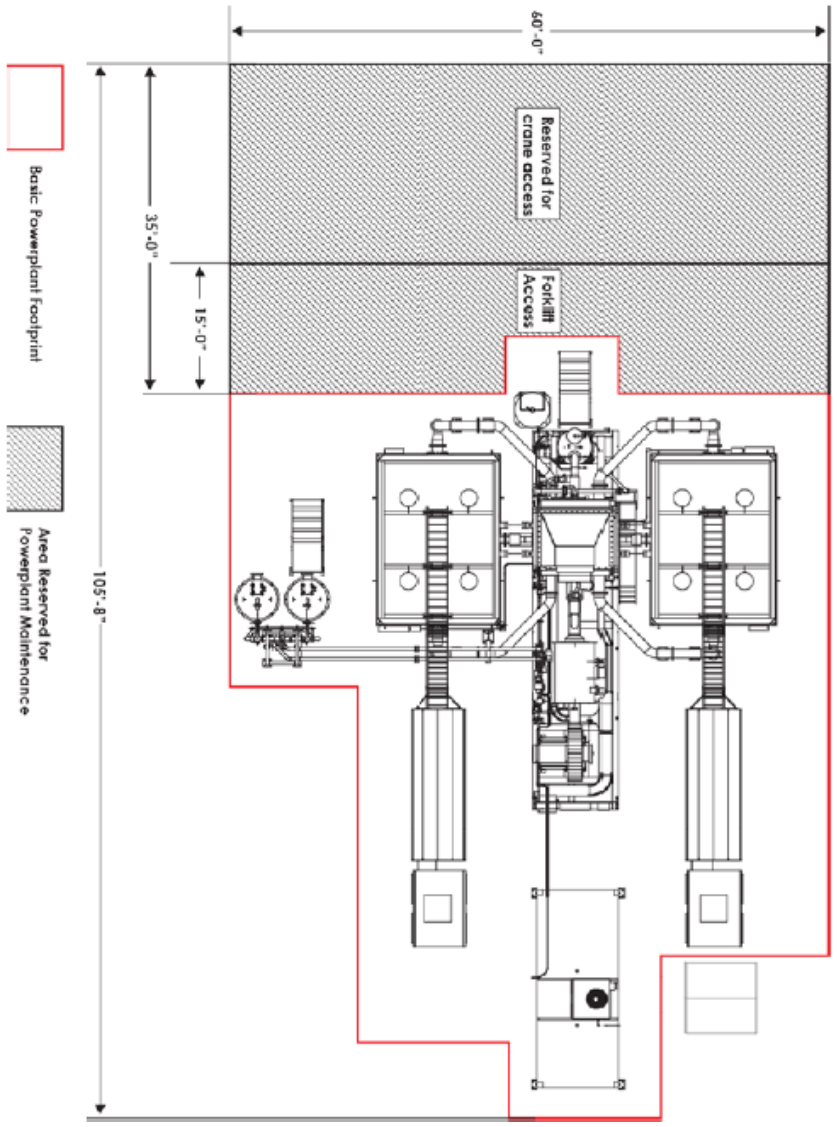

Table 12: Exhaust Temperature to Available Heat Energy

Exhaust Temperature Cooled To (Deg F)	Estimated Heat Energy Available For Heat Recovery (Btu/h)		Total efficiency with heat recovery [4]
	BOL [2]	EOL [3]	BOL
300	3,953,000	4,308,000	68%
250	4,433,000	4,832,000	71%
200	4,913,000	5,355,000	73%
150	5,389,000	5,874,000	76%

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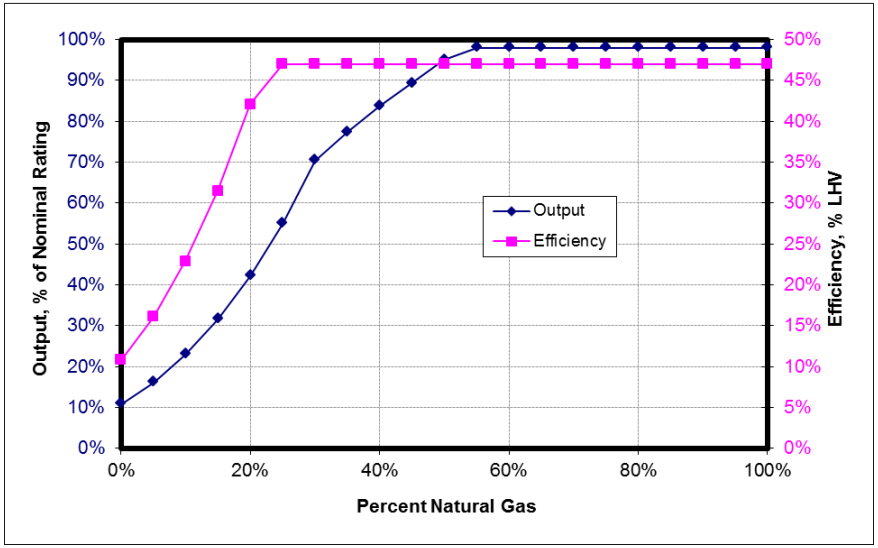
Fuel Requirements

Fuel Composition

- Output, Efficiency constant to 55% CH_4
- CO_2 doesn't need to be removed
- More dilute compositions can be tolerated with derating
- Fuel blending capability installed for process interruptions
- Delivery pressure 15 psig



Fuel Quantity

- 1.4 MW: 310 CFM, 240 MMBtu/day, ~400K population
- 2.8 MW: 620 CFM, 480 MMBtu/day, ~800K population

Source	Gas production per head (cubic feet/day)	Energy content (Btu/h)	Energy content Watts	Electrical output Watts
Human	1	25	7.32	3.44
Swine	4	100	29.30	13.77
Beef	46	1150	336.95	158.37
Dairy	28	700	205.10	96.40
Poultry	0.29	7.25	2.12	1.00

Source: John Balsam, ATTRA Publication IP219, Slot 218, Ver 102506, 2006.

Fuel Quality

- Total Sulfur <10 ppmv, individual species lower
- Siloxanes <100 ppbv
- Total Metals <1 ppmv, individual metals lower
- Moisture: gas delivered at 15 °F above dewpoint

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On-site Power & Heat

Project Overview

1.4 MW combined heat & power fuel cell plant located on the campus of Central Connecticut State University – New Britain providing ~ 1/3 of campus power needs

1.4 MW utility-owned power plant at CCSU – New Britain

Benefits

- High efficiency drives favorable economics
  - CHP for heating and absorption chilling
- Ultra-clean emission profile supports CCSU sustainability goals
- Micro-grid enhances campus energy security
- Private capital providing public benefits

CENTRAL CONNECTICUT STATE UNIVERSITY 1849

GREENWOOD ENERGY

"This power plant is a significant step in helping CCSU achieve our aggressive goals for reducing greenhouse gases and improving energy efficiency on campus," said ***Central Connecticut State University President Jack Miller.***

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UCSD Directed Biogas

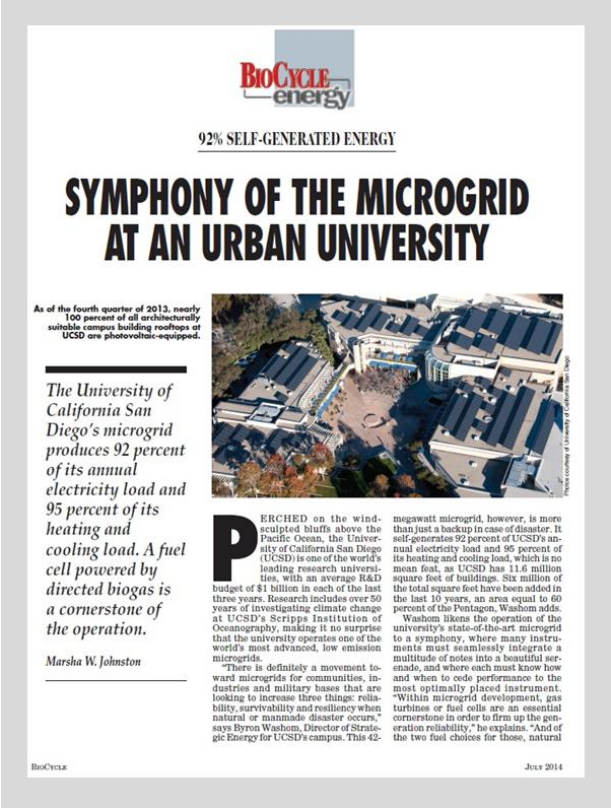
Grid-connected 2.8 MW fuel cell powered by Directed Biogas providing electricity and absorption chilling to campus grid

Benefits

- Fuel cell under PPA – no up-front capital
- ITC monetized, savings passed to UCSD
- UC carbon neutrality by 2025
- Full 42 MW system saves $800K per month

Features

- 42 MW total from gas turbine, fuel cell, PV and energy storage – provides 92% of campus electric load and 95% of heating and cooling load
- Fuel cell operates at ~68% overall efficiency
- Directed biogas from Point Loma wastewater treatment plant
- In operation since 2012



BioCycle energy

92% SELF-GENERATED ENERGY

SYMPHONY OF THE MICROGRID AT AN URBAN UNIVERSITY

As of the fourth quarter of 2013, nearly 100 percent of all architecturally suitable campus building rooftops at UCSD are photovoltaic-equipped.

The University of California San Diego's microgrid produces 92 percent of its annual electricity load and 95 percent of its heating and cooling load. A fuel cell powered by directed biogas is a cornerstone of the operation.

Marsha W. Johnston

PERCHED on the wind-sculpted bluffs above the Pacific Ocean, the University of California San Diego (UCSD) is one of the world's leading research universities, with an average R&D budget of $1 billion in each of the last three years. Research includes over 50 years of investigating climate change at UCSD's Scripps Institution of Oceanography, making it no surprise that the university operates one of the world's most advanced, low emission microgrids.

"There is definitely a movement toward microgrids for communities, industries and military bases that are looking to increase three things: reliability, survivability and resiliency when natural or manmade disaster occurs," says Byron Washom, Director of Strategic Energy for UCSD's campus. This 42-megawatt microgrid, however, is more than just a backup in case of disaster. It self-generates 92 percent of UCSD's annual electricity load and 95 percent of its heating and cooling load, which is no mean feat, as UCSD has 11.6 million square feet of buildings. Six million of the total square feet have been added in the last 10 years, an area equal to 60 percent of the Pentagon, Washom adds.

Washom likens the operation of the university's state-of-the-art microgrid to a symphony, where many instruments must seamlessly integrate a multitude of notes into a beautiful serenade, and where each must know how and when to cede performance to the most optimally placed instrument. "Within microgrid development, gas turbines or fuel cells are an essential cornerstone in order to firm up the generation reliability," he explains. "And of the two fuel choices for those, natural

BioCycle JULY 2014

City of Riverside

Riverside Water Quality Control Plant (RWQCP) just signed a Power Purchase Agreement with FuelCell Energy to purchase electricity and waste heat from a 1.4 MW fuel cell.

Benefits

- Renewable baseload power solves waste disposal problem and provides continuous clean power
- FuelCell Energy will design, manage and operate the biogas clean-up skid.
- Ultra-clean power facilitates clean air permitting
- Distributed generation enhances power reliability and energy security
- High efficiency drives economics

Aerial view of the RWQCP Expansion Progress

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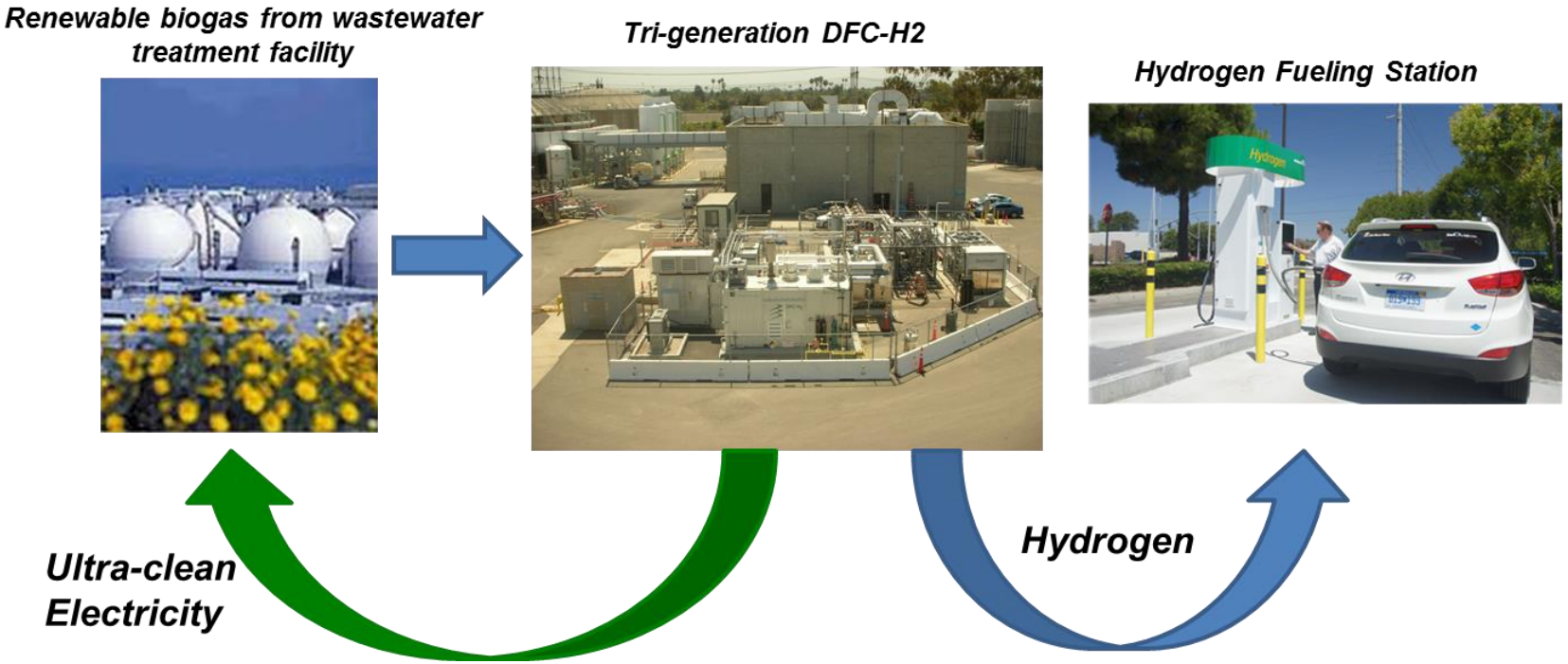
Renewable Hydrogen

Orange County Sanitation District, Fountain Valley CA

- Co-produced hydrogen with power and heat from clean fuel cell systems: tri-generation
- Produced 250 lb/day of renewable hydrogen from Anaerobic Digester Gas
- Supported fleet of 30 fuel cell vehicles in Southern California



Proposed 2.3MW Tri-generation System

Standard Configuration Output, kW	2,800
DFC-H2 Configuration Output, kW	2,350
Hydrogen Production, kg/day	1,270

Possible H_2 Uses

Cars/day, 4.2 kg each*	300
Buses/day, 25 kg each	50
Fork Lifts/day, 2.1 kg each	600

Plant layout would be ~100' x 100', with flexibility for equipment location

* Since cars are not fueled daily, the fleet served by a station would be ~10 times the number of cars visiting the station on a given day

Real World Experience

Integrated Approach Builds on Experience

- 15 MW of bio gas powered fuel cell plants currently installed
- Highly reliable when fuel quality and quantity are within spec
- All fuel clean-up engineering, design & operations are done in-house
  - Extensive engineering & technology capability
  - Pre-qualified, integrated supplier base
  - Well trained, experienced Construction & Service teams
- Maintenance services:
  - 15 to 20 year term, same as fuel cell plant
  - Timely and correct preventive maintenance, including gas sampling
  - Standardized procedures, consumables, and parts across the fleet
  - Maintenance intervals synchronized with fuel cell plant maintenance
- Seamless integration with fuel cell plant control & monitoring system

Bottom line – higher uptime, increased savings, all technology risk removed from Client

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Project Finance Options

- Comprehensive Engineering, Procurement, and Construction services – leverages FCE strength and experience, lowers risk and distractions to Client
- PPA, Lease, Debt Financing
- PPA, Operating lease enable 30% ITC at Universities, Hospitals, Non-Profits
- $40M revolving fuel cell project finance fund with NRG
- Comprehensive Service Agreements with guarantees of fuel cell performance

nrg SM

Dominion

No up-front capital, energy cost savings, low risk

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Fuel Cell Incentives

WESTERN U.S.

CA SGIP Program

- Up to $5 million/project
- 50% received at COD
- SGIP + ITC can't exceed 70% of total project cost

EASTERN U.S.

Eastern States Incentives

- NJ: CHP/FC $3,000/kW
- CT: LREC, 10 MW Utility Program
- NY: REC Program, Fuel Cell PON, Net-Metering applies, NY Prize Micro-Grid Program.

+ +

FEDERAL INCENTIVE

- Investment Tax Credit (ITC) 30% through 2016
- Efficiency enhancement in Congress

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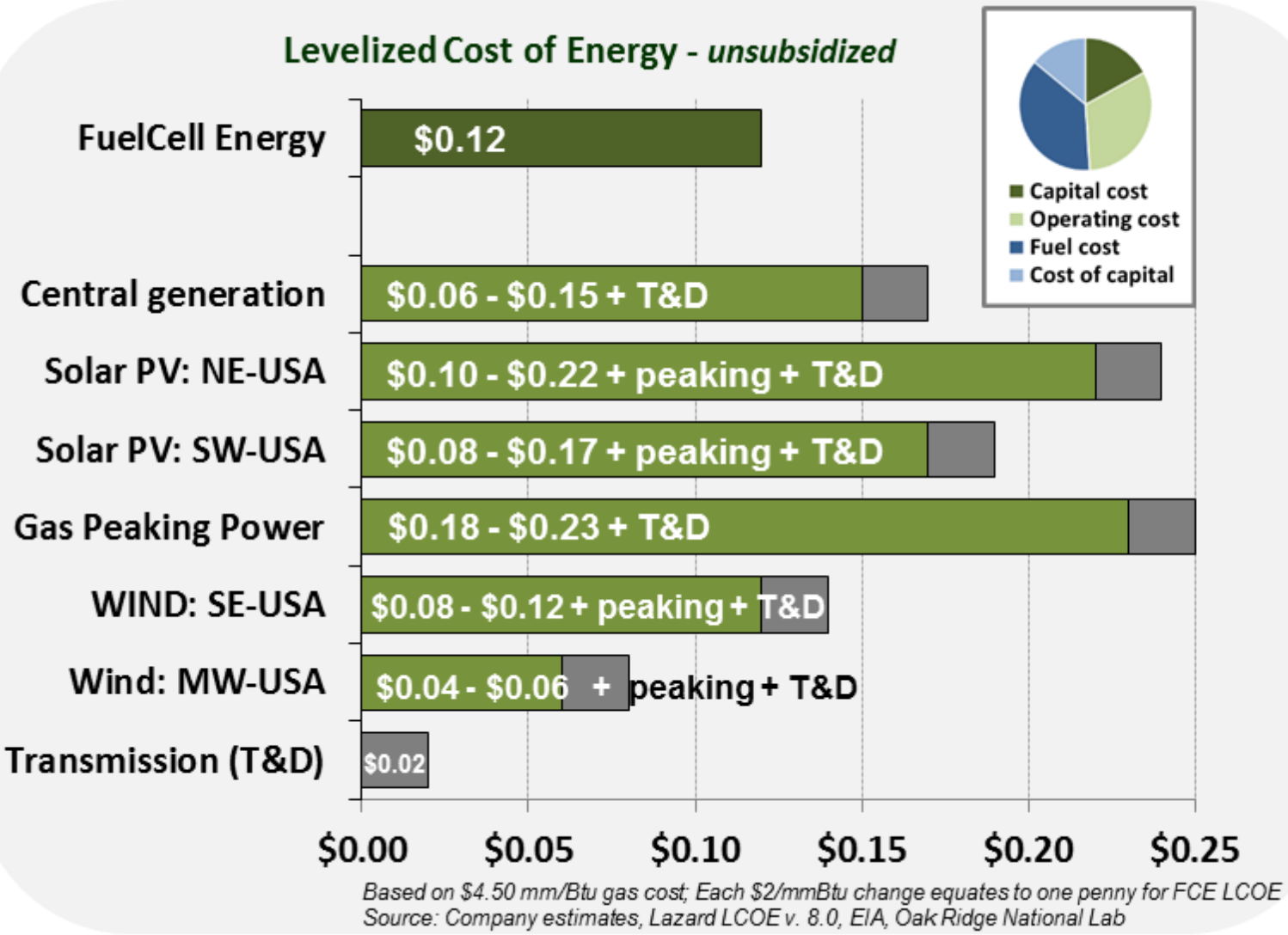
Energy Cost Savings



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Thank you!

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Sign up for the RPP e-Distribution List to get notices of future webinars and the monthly *Resilient Power Project Newsletter*: http://bit.ly/RPPNews-Sign-UP

More information about the Resilient Power Project, its reports, webinar recordings, and other resources can be found at www.resilient-power.org.

Upcoming Webinars

- **Oregon Department of Energy – Energy Storage Demonstration RFP Information Session**, Monday, September 14, 2:30-3:30 pm ET
- **Energy Storage Market Updates** (first in a series), Wednesday, September 30, 1-2 pm ET
- **Fuel Cells for Educational Facilities**, Thursday, October 8, 3-4 pm ET

Contact Info

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