Renewable H_2 from DFC® Fuel Cell

Renewable Hydrogen Co-Production from a High Temperature Fuel Cell

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POWERING A CLEANER FUTURE **TODAY**

FuelCell Energy

Acknowledgement

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- Air Products and Chemicals, Inc. (DOE-EERE)
- FuelCell Energy, Inc.

Disclaimer

This presentation contains forward-looking statements, including statements regarding the company's plans and expectations regarding the development and commercialization of fuel cell technology. All forward-looking statements are subject to risks and uncertainties that could cause actual results to differ materially from those projected. The forward-looking statements speak only as of the date of this presentation. The company expressly disclaims any obligation or undertaking to release publicly any updates or revisions to any such statements to reflect any change in the company's expectations or any change in events, conditions or circumstances on which any such statements are based.

Background – FuelCell Energy

- **#1 high temperature stationary fuel cell manufacturer and developer including carbonate and solid oxide applications**
- **Delivering commercial products with advanced Direct FuelCell® technology**
- **Over 43 MW of electricity generating capacity installed/on order to date**
  - California/West Coast: 19.6 MW
  - Japan/Korea: 18.0 MW
  - Northeast/Canada: 4.5 MW
  - Europe: 1.3 MW
- **Headquarters in Danbury, CT**
  Manufacturing Facilities in Torrington, CT
  SOFC Division in Calgary, Alberta, Canada
- **NasdaqNM:FCEL**

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Background – Air Products

- Major Supplier of Industrial Gases
- Prime contractor for DOE contract to demonstrate a Hydrogen Energy Station (HES) to provide H2, power and heat
- Expert in PSA technology used for purification of hydrogen from syngas, including gas generated by high temperature fuel cells
- Expert in H2 filling stations with over 70 built world wide

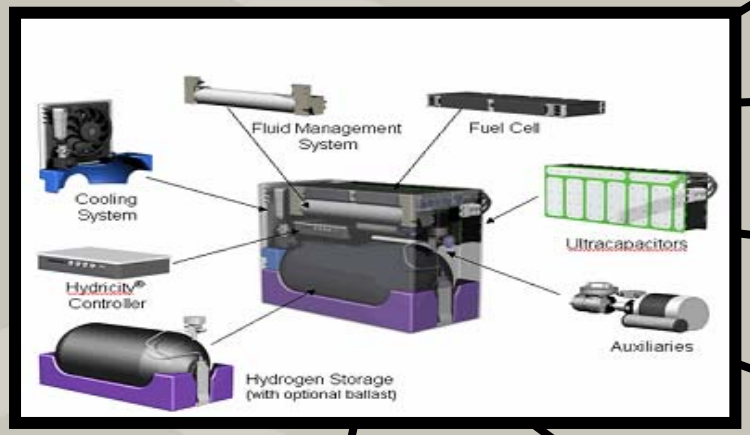
Background – DOD

- **Major user of fuels**
- **Goal to maximize renewable energy use**
  - **Near term H2 for fork lifts**

***Nation's single largest energy user** (1% of total U.S. energy use & 78% of Federal energy use)*

Direct benefit to military applications

- **Increased Fuel Efficiency**
- **Quiet, low-heat, zero-emissions**
- **Energy density**
- **Fuel diversity**

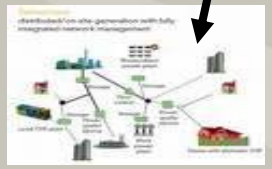


Soldier Power

COMBATT APU

UAV **UUV**

DDX



Micro-grids

Portable Gen-sets

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FuelCell Energy Commercial Fuel Experience

- **Fuels that commercial DFC products have operated on:**
  - **Pipeline natural gas**
  - **Liquid Natural Gas or LNG**
  - **Anaerobic Digester Gas or ADG**
  - **Propane (Demonstrated, Unit on Order)**
  - **Coal mine methane (Demonstration Only)**
- **FCE has limited experience with the following fuels, but they can used if properly treated:**
  - **Land Fill Gas or LFG**
  - **Synthesis gas or Syngas**

Renewable Fuels

Note: Depending on composition, fuels other than natural gas and ADG may require de-rating of powerplant output.

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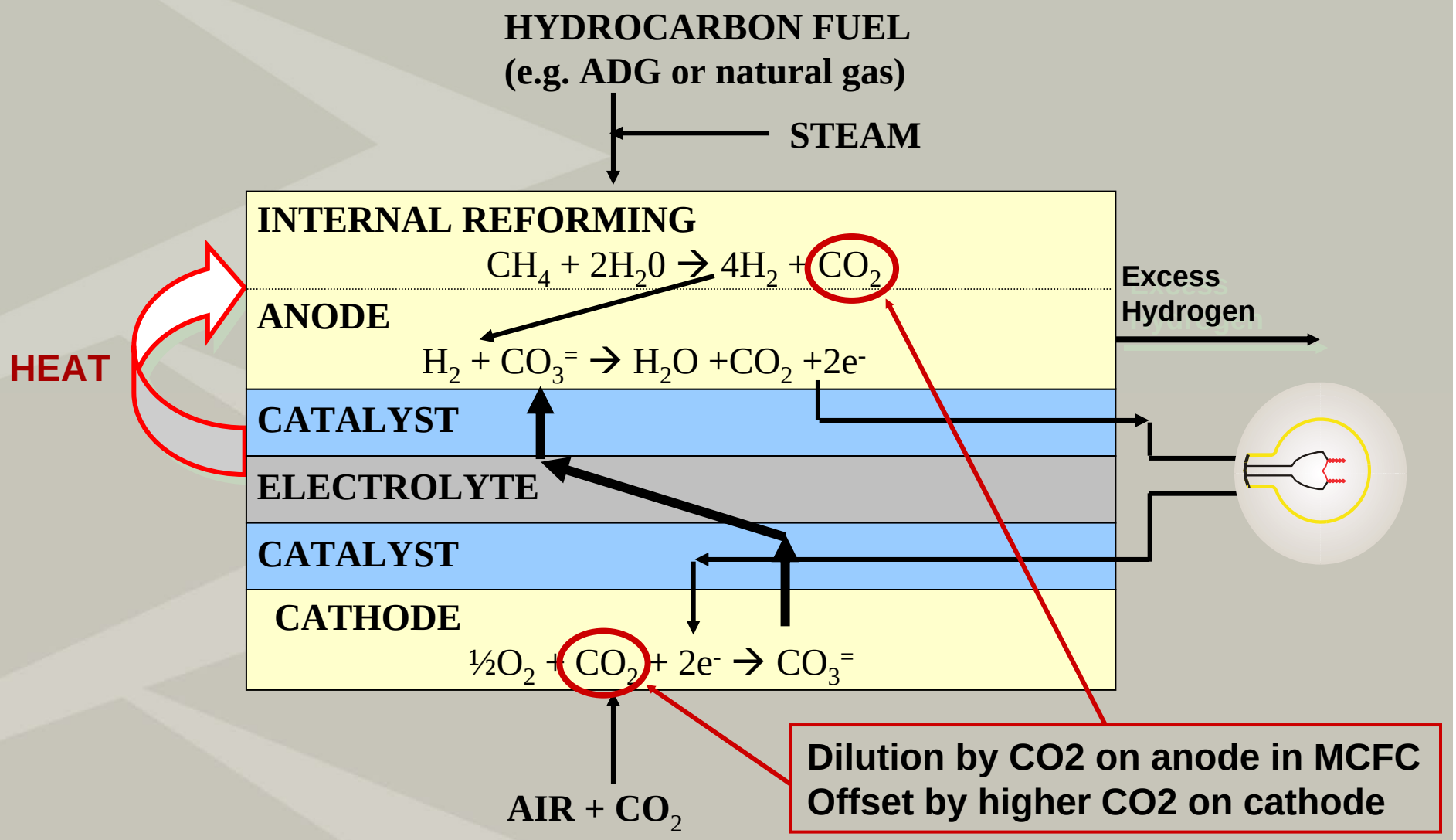
Operation –Carbonate DFC® Technology



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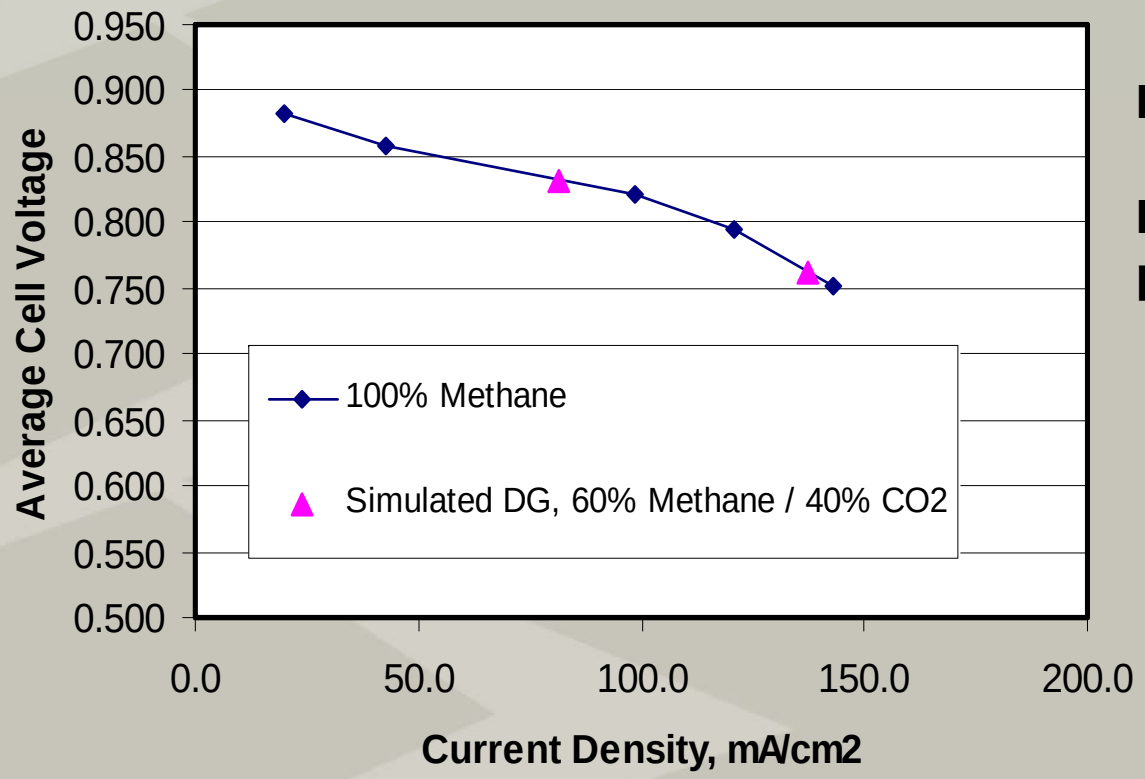
Operation –Carbonate DFC® Technology

DFC units uniquely suitable for renewable fuel

- **No derating**
- **No performance loss**



Derating greatly increases $/kw

Performance loss lowers KW produced from given digester

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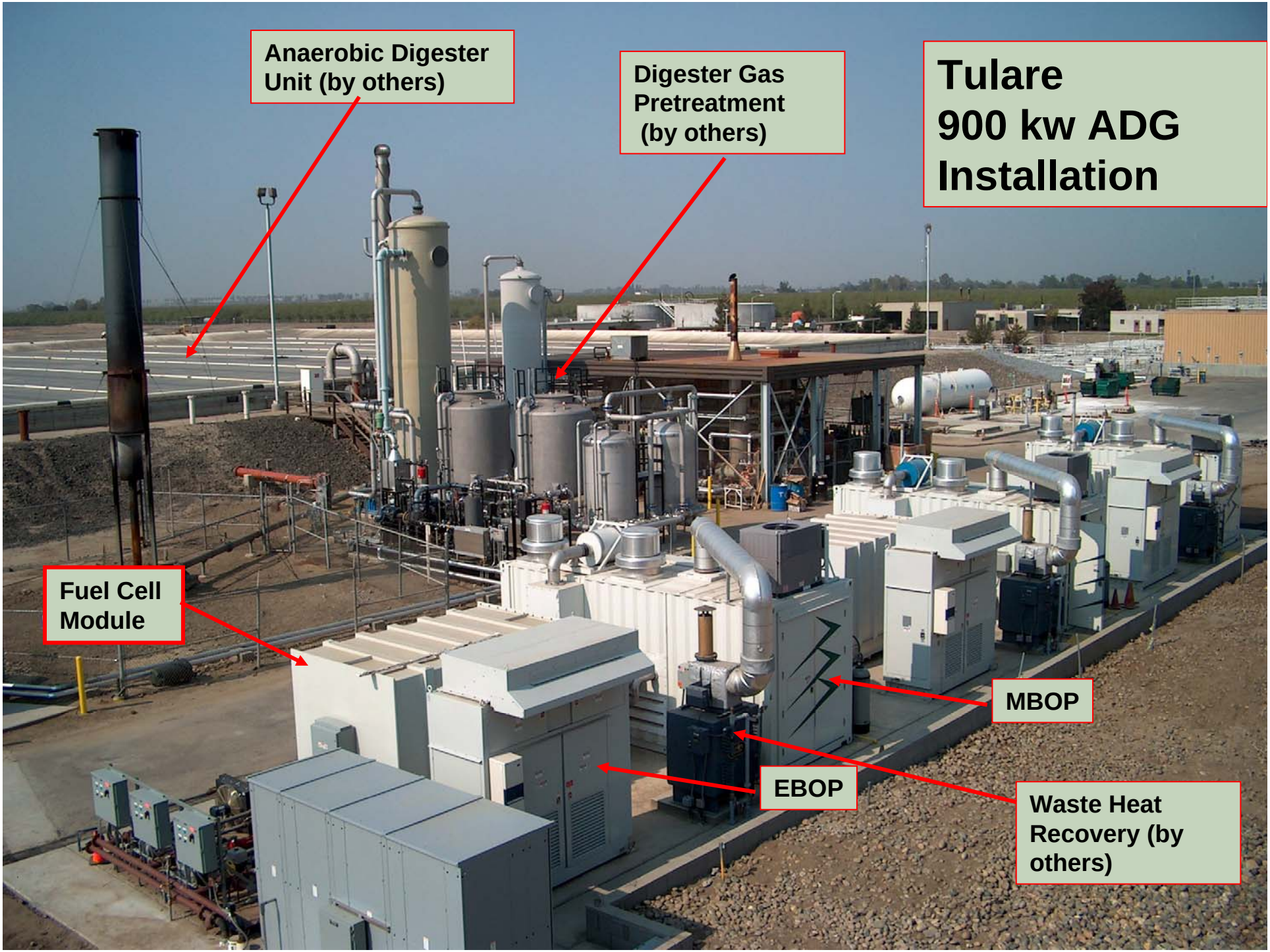
Overview of Direct FuelCell Biogas Applications

Site	Power plant Model (s)	Fuels (s)
King County Wastewater Treatment Plant, Renton WA	1 x DFC1500	ADG, NG
Kirin Brewery, Toride Japan	1 x DFC300	ADG, C3 backup
City of Fukuoka Treatment Plant, Fukuoka Japan	1 x DFC300	ADG
LA Sanitation Palmdale WWT Plant, Los Angeles, CA	1 x DFC300	ADG
City of Santa Barbara El Estero WWT Facility, CA	2 x DFC300	ADG
Sierra Nevada Brewery Company, Chico, CA	4 x DFC300	ADG/NG blending
Tokyo Super Eco Town food recycling facility, Japan	1 x DFC300	ADG
Kyoto Eco-Energy Project (KEEP) food processing plant waste, Kyoto, Japan	1 x DFC300	ADG
Tancheon Sewage Treatment Plant, Seoul, Korea	1 x DFC300	ADG
Ahlen Wastewater Treatment Facility, Germany	1 x HotModule	ADG
City of Tulare WWT Facility, Tulare, CA	3 x DFC300	ADG
Dublin San Ramon Services District WWT facility, Pleasanton CA	2 x DFC300	ADG
City of Rialto WWT facility, Rialto, CA	3 x DFC300	ADG

Overview of Direct FuelCell Biogas Applications

Units on Order Site	Power plant Model (s)	Fuels (s)
Gills Onion food waste processing facility, Oxnard, CA	2 x DFC300	ADG
City of Riverside WWT facility, Riverside, CA	1 x DFC1500	ADG
Turlock Irrigation District WWT facility, Turlock, CA	1 x DFC1500	ADG
Eastern Municipal Water District WWT facility, Moreno Valley, CA	3 x DFC300	ADG
Linde Group, distributed biogas, San Diego, CA	3 x DFC1500, plus 1x DFC300	ADG

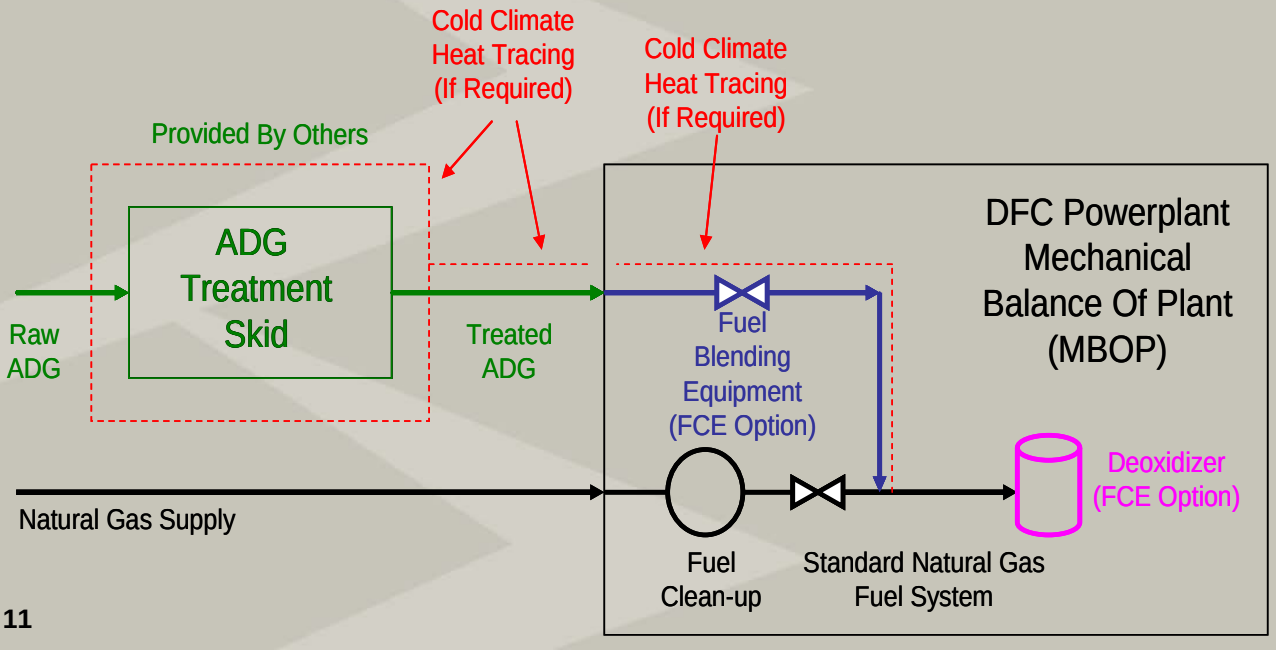
- 11 Current locations in California;
- 26 units;
- 16 MA units which are easily converted to H2 production


Anaerobic Digester Unit (by others)
Digester Gas Pretreatment (by others)
Tulare 900 kw ADG Installation
Fuel Cell Module
MBOP
EBOP
Waste Heat Recovery (by others)

Fuel Blending / Switching Option

- **The fuel blending option is recommended for maximum reliability.**
- **Blending control logic maximizes the use of ADG**
  only blends in natural gas when full ADG flow is unavailable.
- **Switches completely to natural gas when no ADG is available.**

For fuel blending applications,
the ADG is cleaned in an ADG Treatment Skid.



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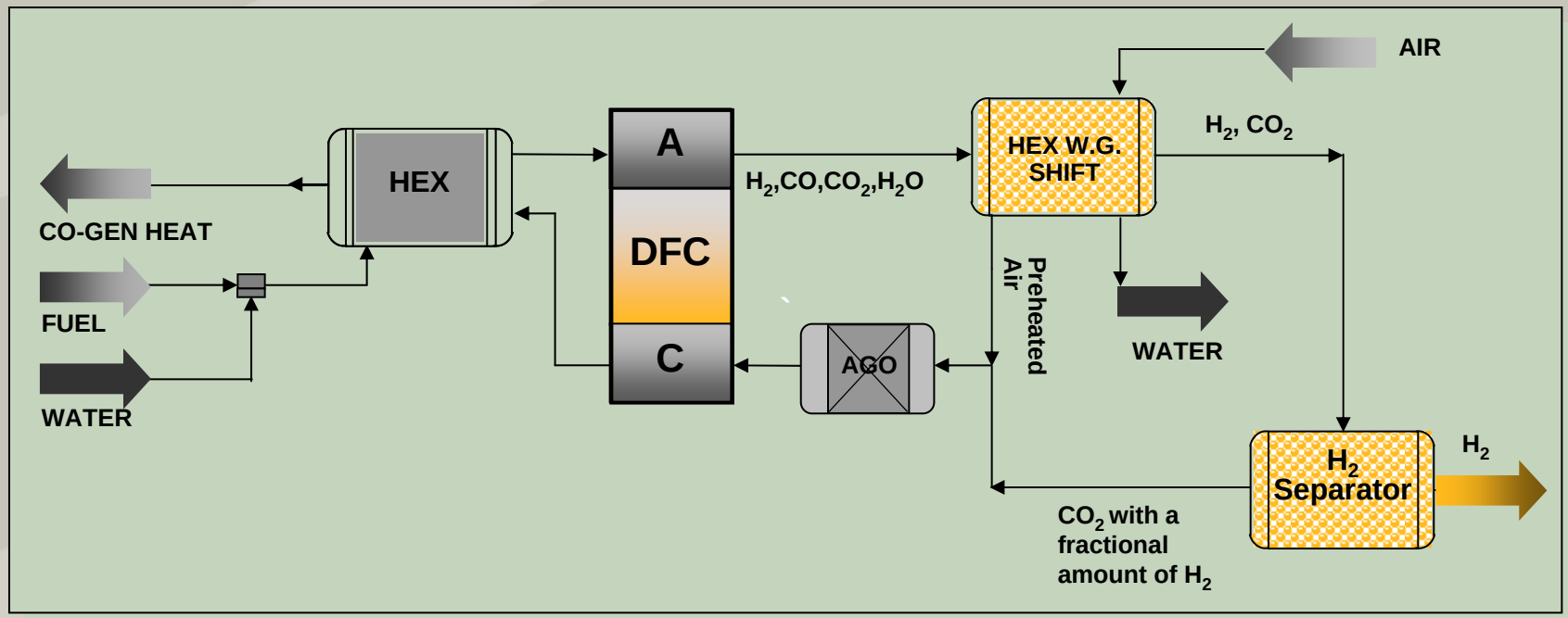
Configuration – H2 Recovery



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Anode Outlet Gas (H2 Source)

Composition

	ADG Feed		NG Feed	
		Dry / Shifted		Dry / Shifted
H2	11%	23%	13%	28%
H2O	36%	-	39%	-
CO	6%	1%	6%	1%
CO2	47%	76%	41%	71%

Anode Gas needs to be cooled, pressurized and purified, but extracted H2 represents an additional "free" revenue stream for combined H2 + Power solution

Heat and Material Balance with ADG feed

Stream No.	1		2		3	4		5		6	
Name	Air		Feed		Net Power to Grid	Hydrogen		Water Export		Exhaust	
Molar flow lbmol/h	86.24		12.25		**245 kw**	7.43		4.73		90.44	
Mass flow lb/h	2,478.6		333.6			15.0		85.3		2,719.1	
Temp F	59 °		75 °			100 °		132 °		319 °	
Pres psia					Gross Power	165					
					306 kw	85.0%	PSA H2 Recovery				
Components	lb-mole/hr	mole fraction	lb-mole/hr	mole fraction		lb-mole/hr	mole fraction	lb-mole/hr	mole fraction	lb-mole/hr	mole fraction
Hydrogen	0.00	.000	0.00	.000	Power H2	7.43	1.000	0.00	.000	0.00	.000
Methane	0.00	.000	7.35	.600	Purification	0.00	.000	0.00	.000	0.03	.000
Carbon Monoxide	0.00	.000	0.00	.000	61 kw	0.00	.000	0.00	.000	0.00	.000
Carbon Dioxide	0.00	.000	4.90	.400		0.00	.000	0.00	.000	12.22	.135
Water	0.87	.010	0.00	.000	Waste Heat	0.00	.000	4.73	1.000	3.74	.041
Nitrogen	67.48	.782	0.00	.000	(to 120°F)	0.00	.000	0.00	.000	67.48	.746
Oxygen	17.89	.207	0.00	.000	53 kw	0.00	.000	0.00	.000	6.96	.077
Ethane	0.00	.000	0.00	.000		0.00	.000	0.00	.000	0.00	.000
Propane	0.00	.000	0.00	.000		0.00	.000	0.00	.000	0.00	.000
I-Butane	0.00	.000	0.00	.000		0.00	.000	0.00	.000	0.00	.000
N-Butane	0.00	.000	0.00	.000		0.00	.000	0.00	.000	0.00	.000
Total	86.24	1.000	12.25	1.000		7.43	1.000	4.73	1.000	90.44	1.000
Heat Content, kw	0.0 kw		743.6 kw		244.6 kw	226.6 kw		0.0 kw		3.0 kw	
% of Feed KW			100.0%		32.9%	30.5%					
Trigeneration Efficiency	**70.5%**	**(Net Power + Hydrogen + Export Heat) / Fuel**									
Power Efficiency	59.1%	Gross Power / (Total Fuel - Hydrogen fuel value)									
Hydrogen Efficiency	73.1%	(Hydrogen - Purification Power) / Hydrogen									
Overall Efficiency	**63.4%**	(Net Power + Hydrogen) / Fuel									

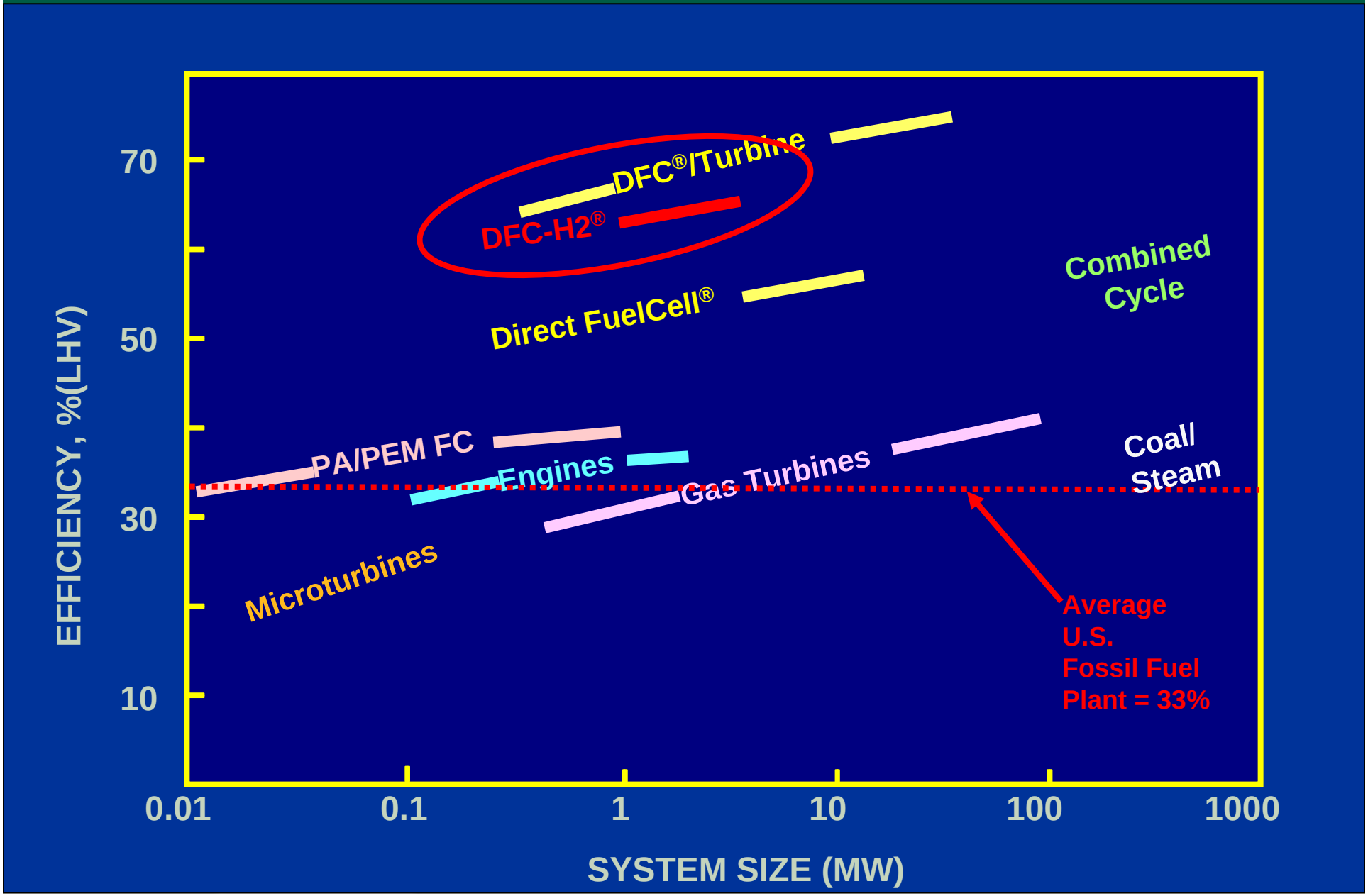
Biogas impact on system performance is minimal

	Units	NG	Biogas
Overall Efficiency (without waste heat) (Net Power + Hydrogen Product) / (Fuel)	LHV	66%	63%
Power Efficiency Net Power / (Total Fuel – Hydrogen Product)	LHV	49%	47%
Hydrogen Efficiency (Hydrogen Product – Purification Power) / Hydrogen Product	LHV	77%	73%
Hydrogen Product	Nm3/hr	~ 80	~76
Net Power w/o & w Hydrogen	kW	~ 300 / 250	~300/240
Natural Gas / Biogas Flow	Nm3/hr	~ 74	~115*

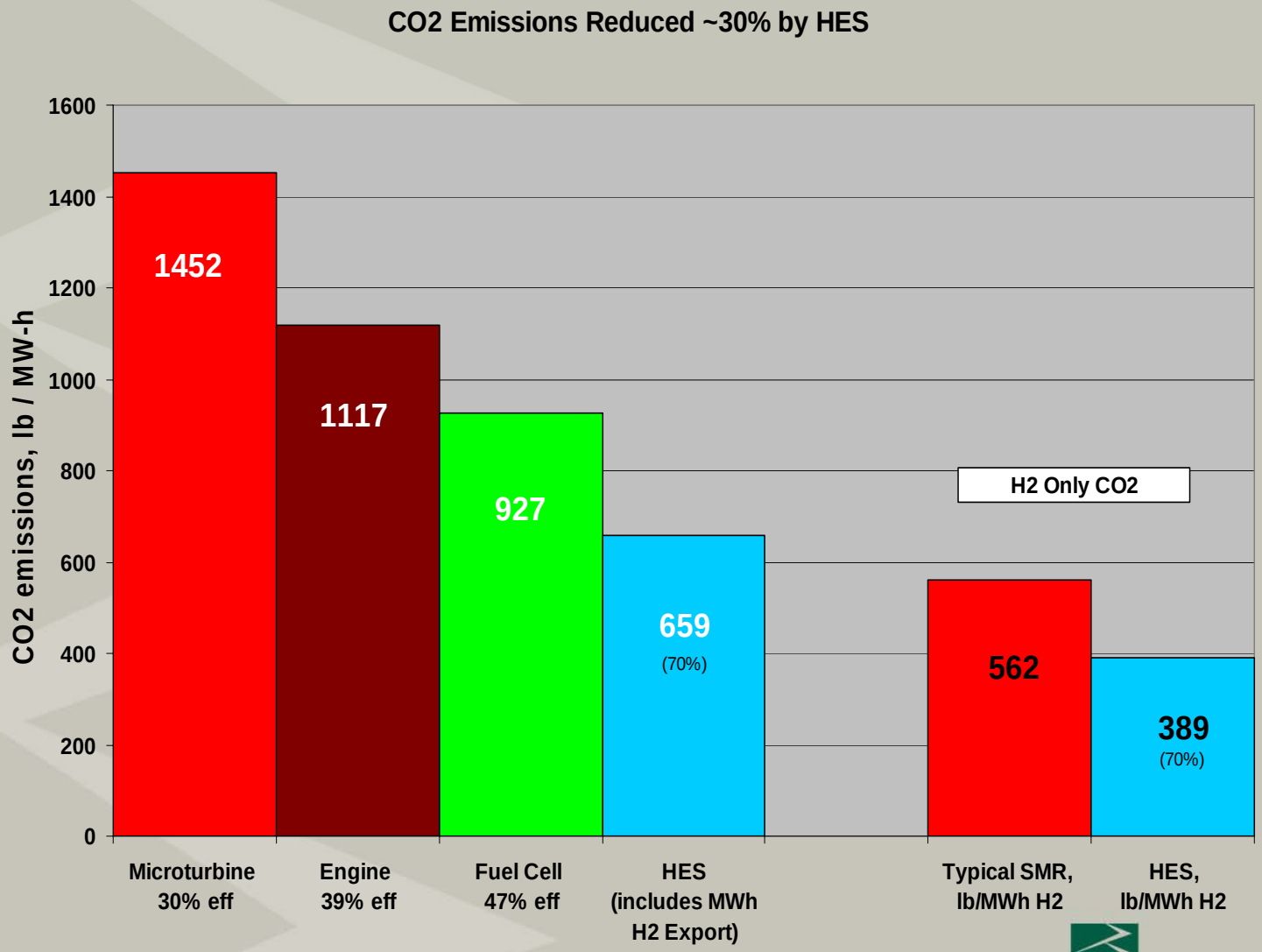
DFC performance has no impact from Biogas
Small impact on PSA performance due to higher CO2 in gas to PSA

* Includes ~70 nm3/hr of methane, balance is CO2

High Efficiency for Distributed Generation of Power and H2



Reduced CO2 Emissions



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NOX and SOX Emissions

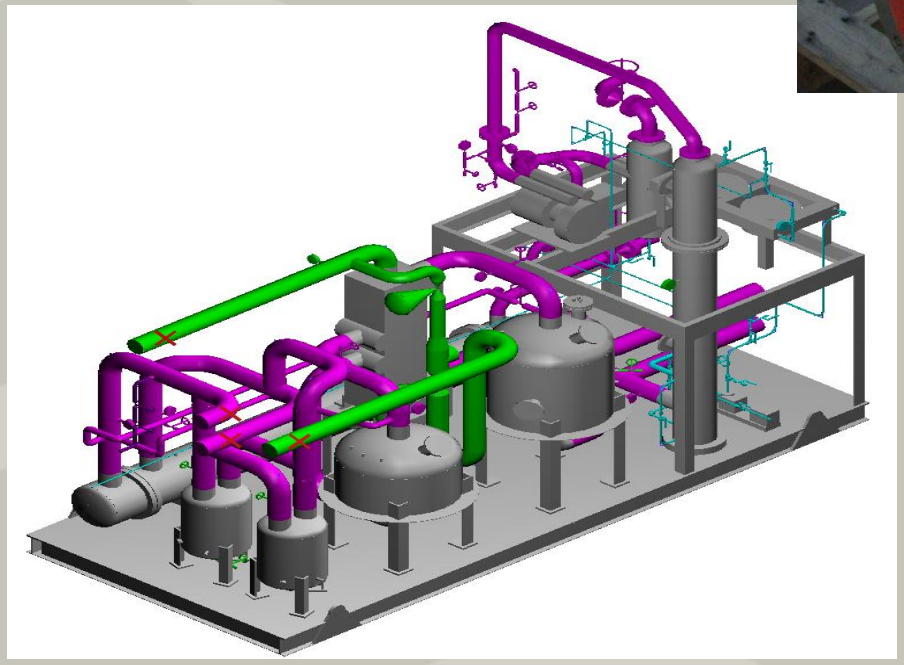
	NO_X (lb/MWh)	SO_X (lb/MWh)	CO_2 (lb/MWh)
Average US Fossil Fuel Plant	4.200	9.21	2,017
Microturbine (60 kW)	0.490	0	1,862
Small Gas Turbine (250 kW)	0.467	0	1,244
DFC Fuel Cell 47% efficiency	**0.016**	**0**	**967**
DFC Fuel Cell – CHP 80% efficiency	**0.016**	**0**	**545**

NO_x and SO_x are negligible compared to conventional technologies

Current Status

- FuelCell Energy and Air Products prototype unit are constructing the first DFC-H2
- Unit will be tested with NG feed this year at FCE's Danbury headquarters
- Unit will be shipped to WWT facility for long term testing and operation on ADG
- Improved designs in progress
  - EHS (Electro-chemical H2 Separation)
  - Close coupled cooling / shift (low cost)
  - Load following operation

Proto-type Unit Currently Under Construction



EHS System Demonstration at University of CT

- The Demo Unit separates 6 lb/day H_2
  – can refuel approximately one car per day
- >10,000 hours of operation to date
- >5,000 hours operation at FCE Danbury Laboratory
- Reliable operation: No EHS-related shutdowns

Celebration of
Successful Completion
of EHS Demo Project
September 2007

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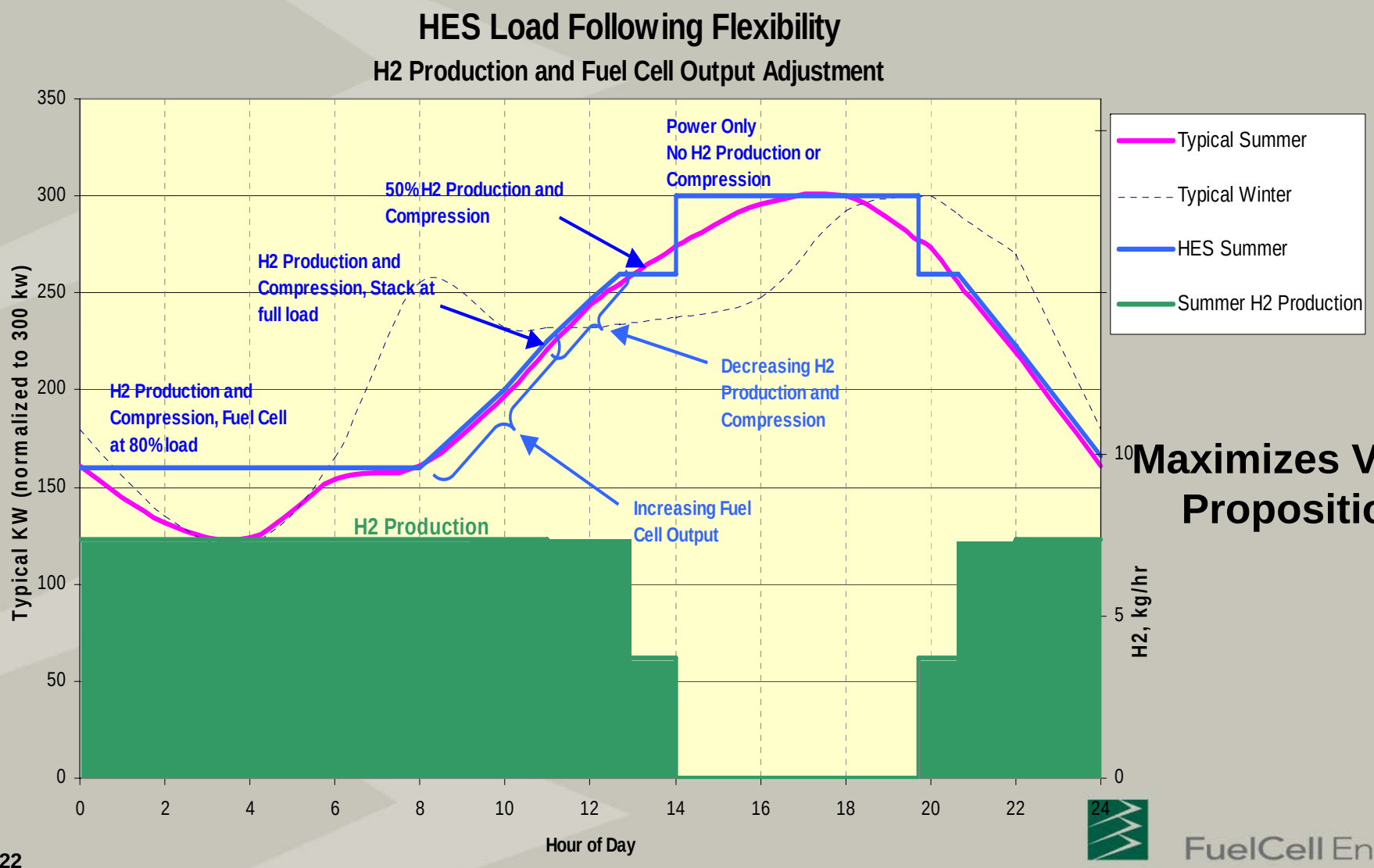
Flexible Co-Production: Load Following



Maximizes Value Proposition

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Relevance to California H2 Highway Initiative

- CARB & AQMD are promoting renewable H2 for Fuel Cell vehicles
- DFC fuel cells are clean; CARB '07 certified; and expected to have no change in emissions with byproduct H2
- Permitting of standard SMR H2 units is getting difficult due to concerns with NOx, SOx emissions and now CO2
- HES provides clean power and green H2
- Distributed H2 production eliminates emissions associated with H2 truck delivery

Conclusions

- Distributed co-production of Hydrogen and Power with a Carbonate (DFC®) fuel cell is attractive
- Current technology is competitive with small scale / distributed H2 production
- Integration of System with Renewable ADG is best method for Renewable H2 production
- Fuel cell's emissions remain extremely low even with H2 production, minimizing siting concerns

DFC-H2 Power Plant: Trigeneration System

DFC-H_2 POWER PLANT

Commercial/Industrial Building

kWs to electric load: 50%

Heat to buildings
thermal load: 15%

Hydrogen: 20%

H_2 – REFUELING STATION

Multiple Co-products
Improve Asset Utilization