



FuelCell Energy

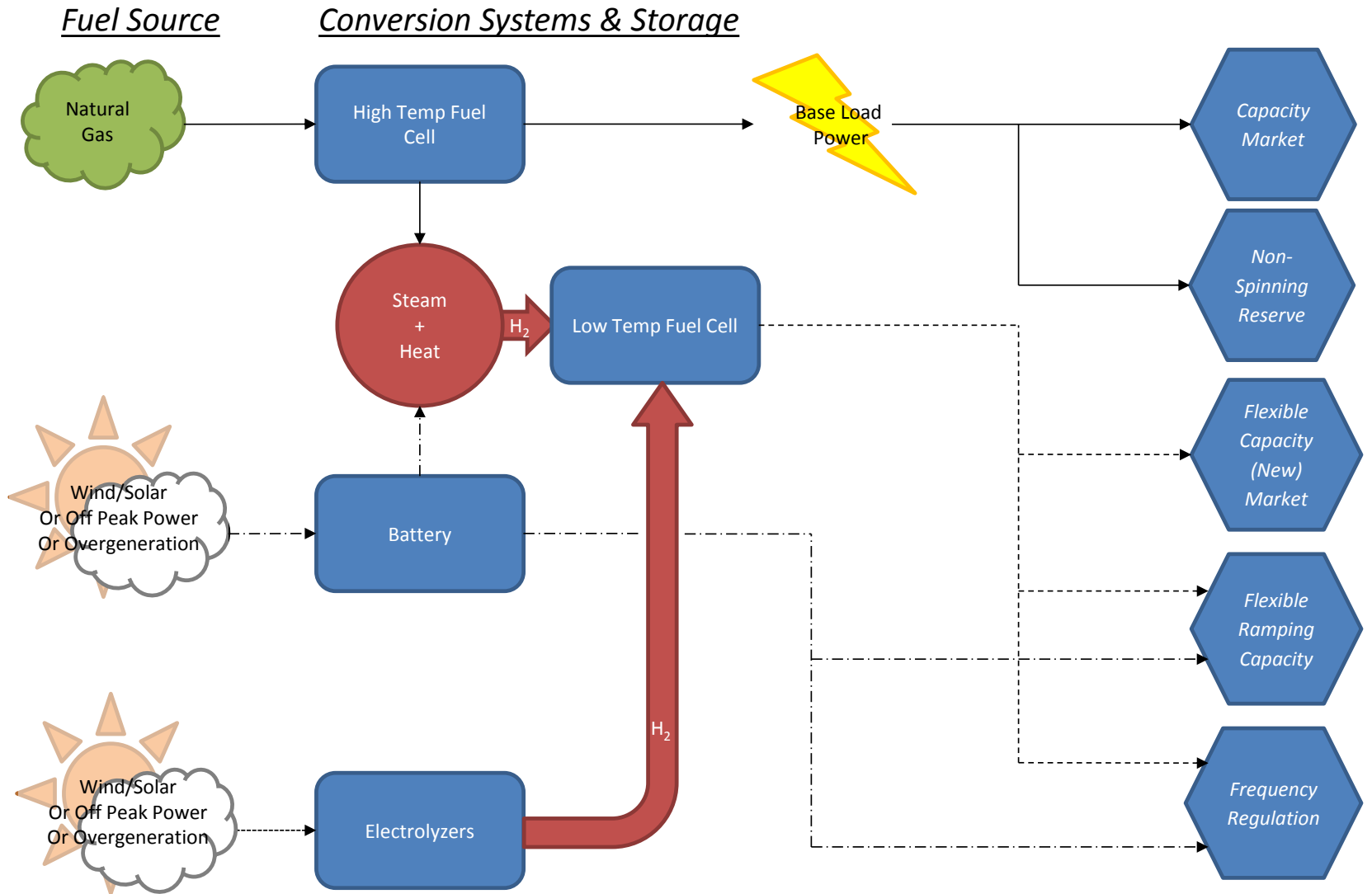
Fuel Cells for Grid Modernization Opportunities and Needs

**Dispatchable Distributed Generation:
Manufacturing's Role in Support of Grid Modernization**

**DOE-AMO Workshop
Austin, TX, February 10-11, 2016**

By Pinakin Patel

Grid Support Services Using Fuel Cells



19 MW in Grid Support in Bridgeport

“These [fuel cell] projects aren’t just good for the environment, they are good for our economy. They create jobs. They help reduce asthma and breathing ailment rates for kids. They grow our tax base.” Bridgeport Mayor Bill Finch (term expired Jan-2016)



UNIVERSITY OF
BRIDGEPORT

NRG YIELD

Type: On-site CHP
Size: 1.4 MW
Owner: Project investor

“Sustainable and affordable energy is an increasingly important component of the new energy mix at the University of Bridgeport.”

Neil A. Salonen President,
University of Bridgeport



Dominion

Type: Grid support
Size: 14.9 MW
Owner: Utility – PPA structure

*“The Dominion Bridgeport Fuel Cell Park is another important step in our efforts to identify and develop opportunities to produce clean energy that is **reliable and cost effective.**”* Thomas F. Farrell II, Chairman,
President and CEO, Dominion



Type: Grid support
w/ solar array
Size: 2.8 MW
Owner: Utility – rate base

*“Purchasing these fuel cell power plants supports our goal of investing in renewable distributed generation to **enhance the reliability of our power delivery system** and offer our customers cleaner energy.”* James P. Torgerson, President & CEO, Avangrid

Enabler for H₂ Infrastructure for Mfg., Transportation and Grid Support



Individual fuel cell
&
350 kW fuel cell stack



Four-Stack Module
1.4 megawatts



Completed module
1.4 megawatts



1.4 MW DFC1500[®]

- Utilizes one module
- Adequate to power 1,400 homes



2.8 MW DFC3000[®]

- Utilizes two modules
- Adequate to power 2,800 homes



59MW fuel
cell park

**DFC provides strong foundation for Tri-gen technology
(70 MW/yr production rate)**

Hydrogen for Energy Storage



**14.9 MW fuel cell park
Bridgeport, CT**



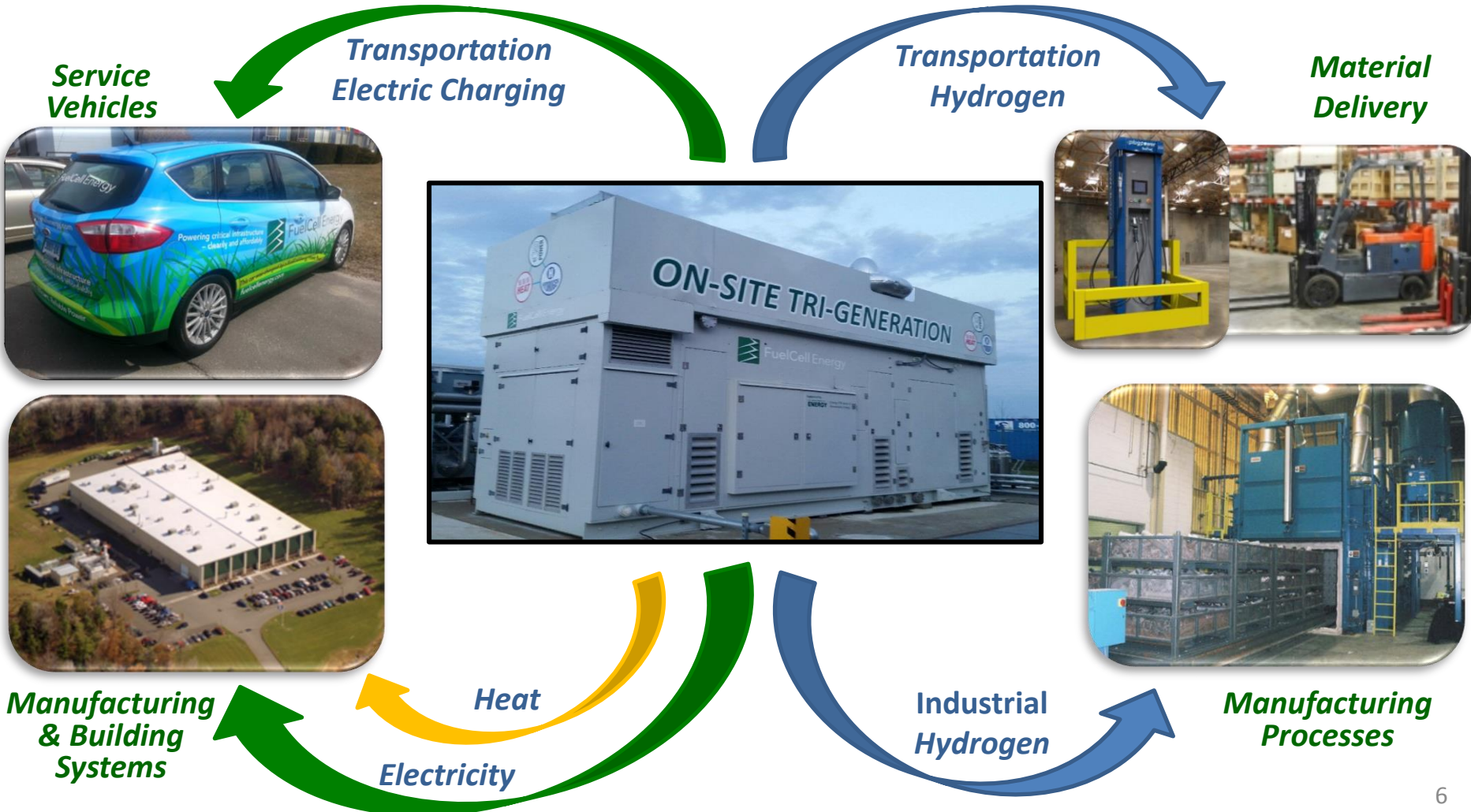
**59 MW fuel cell park
Korea**

	14.9 MW	59 MW
Hydrogen Produced	> 25 tons/day	> 100 tons/day
Hydrogen Available	~ 6 tons/day	~ 24 tons/day
Grid Support	125 MWh	500 MWh

Scale-up to MW scale Tri-gen system is needed

Industrial Application of Tri-Gen

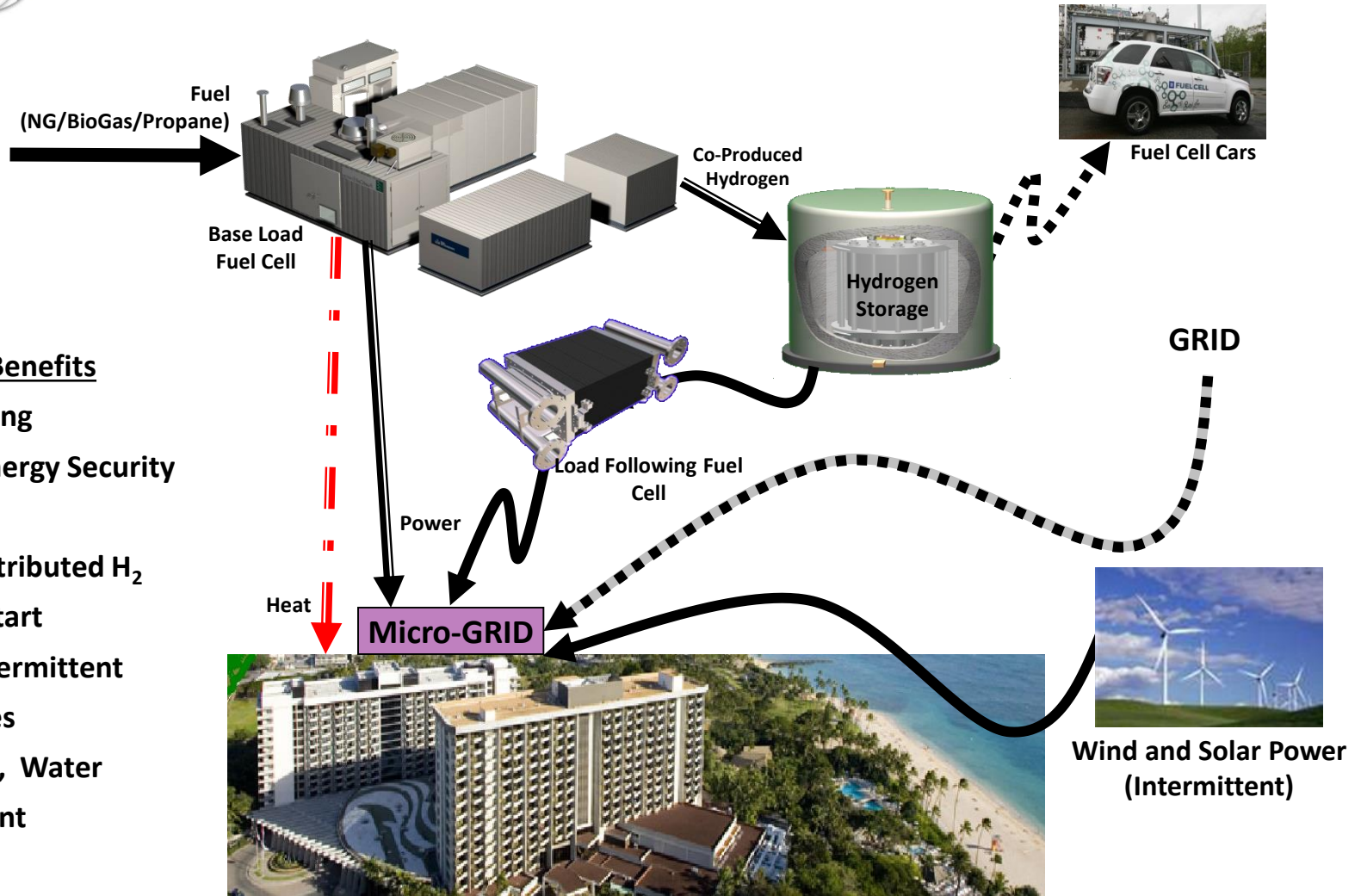
Demonstrating the Value Proposition While Reducing Torrington Operating Costs





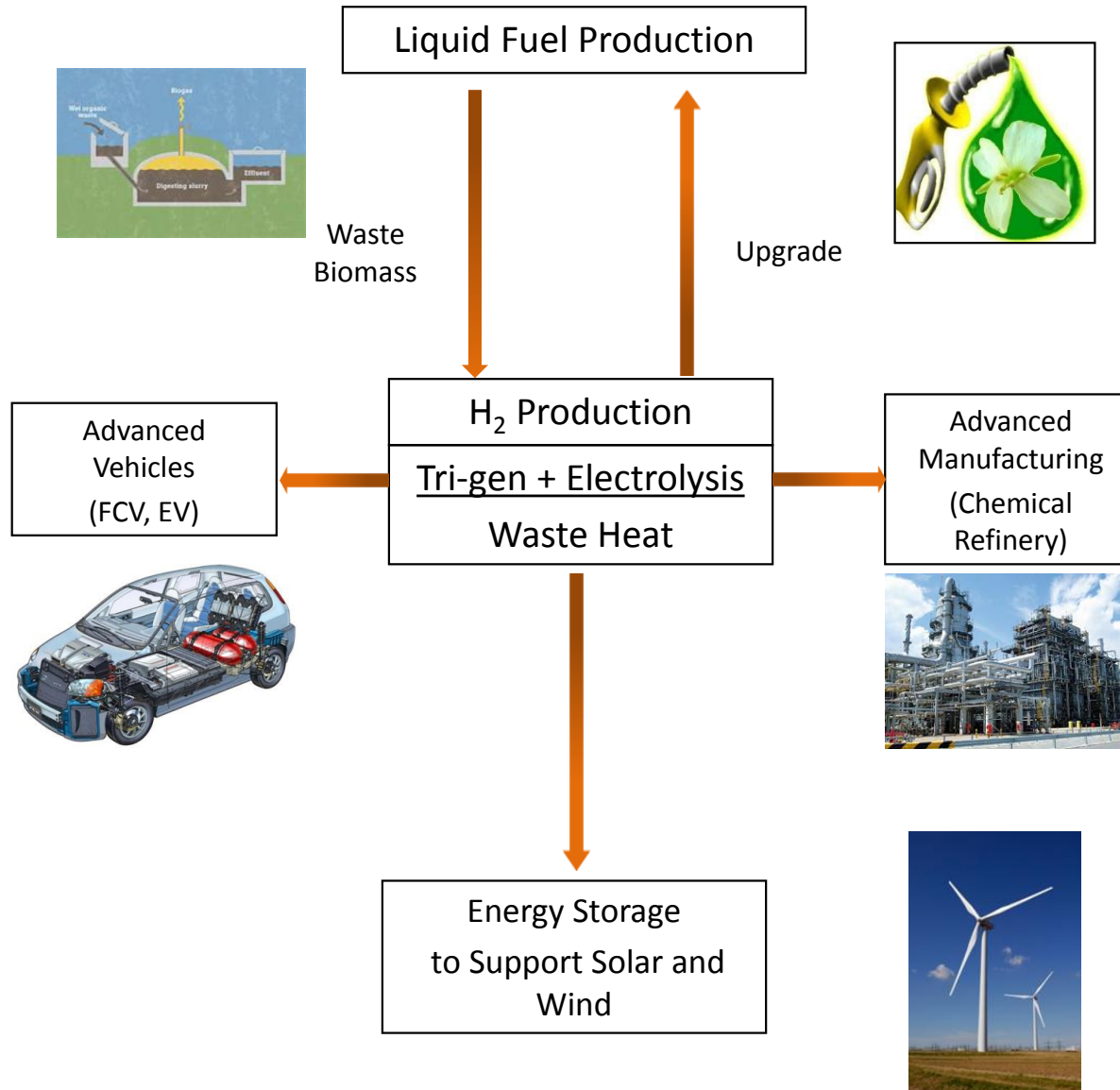
Black Start Capability

- Grid Benefits**
- Load Following
 - Enhanced Energy Security
 - Ultra Clean
 - Provides Distributed H₂ for Black Start
 - Supports Intermittent Renewables
 - Fuel Flexible, Water Independent

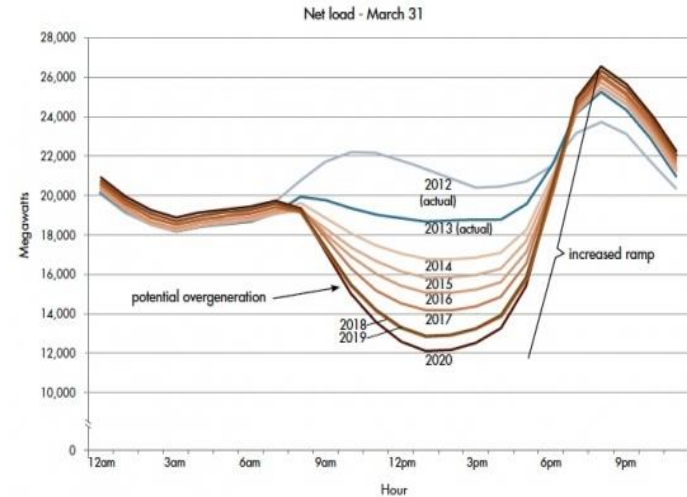
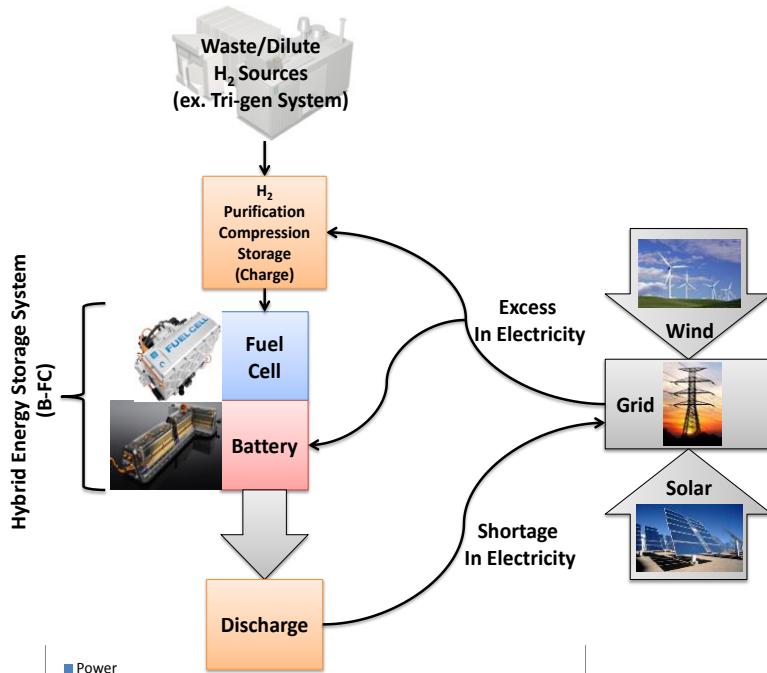


Hydrogen storage for rapid demand response and black start

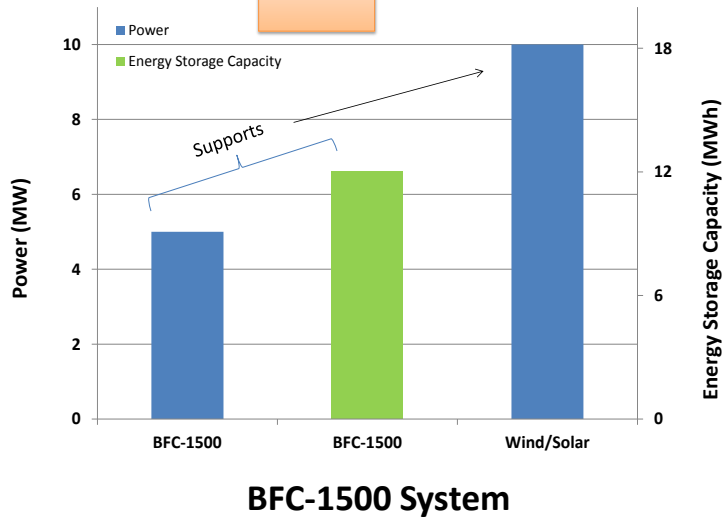
Cross Cutting Role of H₂ Technology



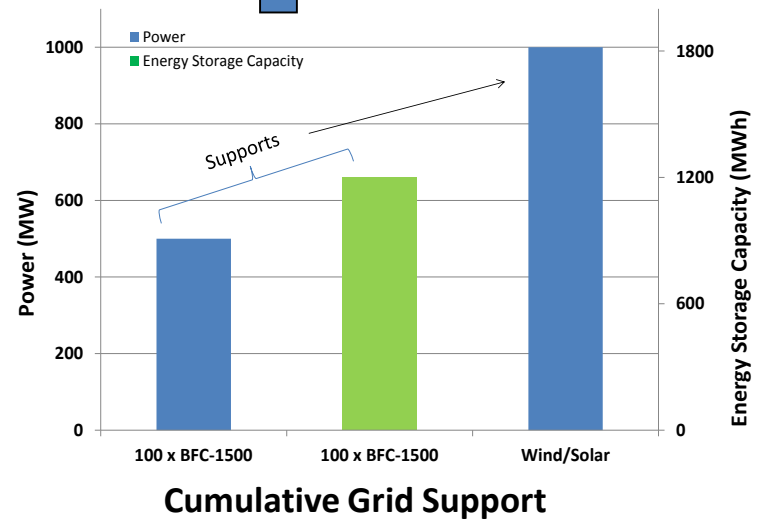
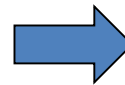
Advanced Energy Storage for Grid Support

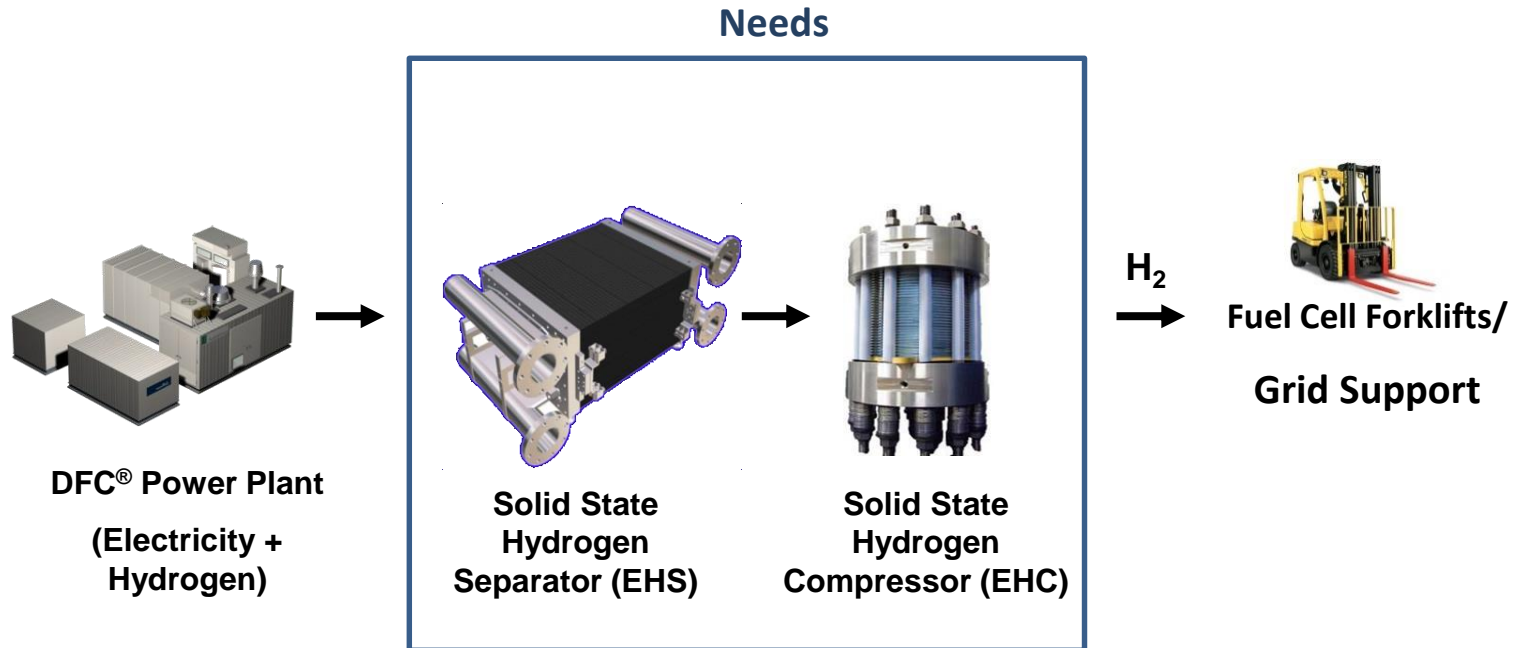


Solution to Duck Curve Issue



x100 Systems





Hydrogen co-production technology is enabler for advanced manufacturing and grid reliability



DG system using Tri-gen/peaker technology to provide grid support/ ancillary services at a manufacturing site offers lower cost solution with higher efficiency, lower GHG footprint and retains domestic jobs

Opportunity to leverage current DOE investment in Tri-gen technology at sub-MW level:

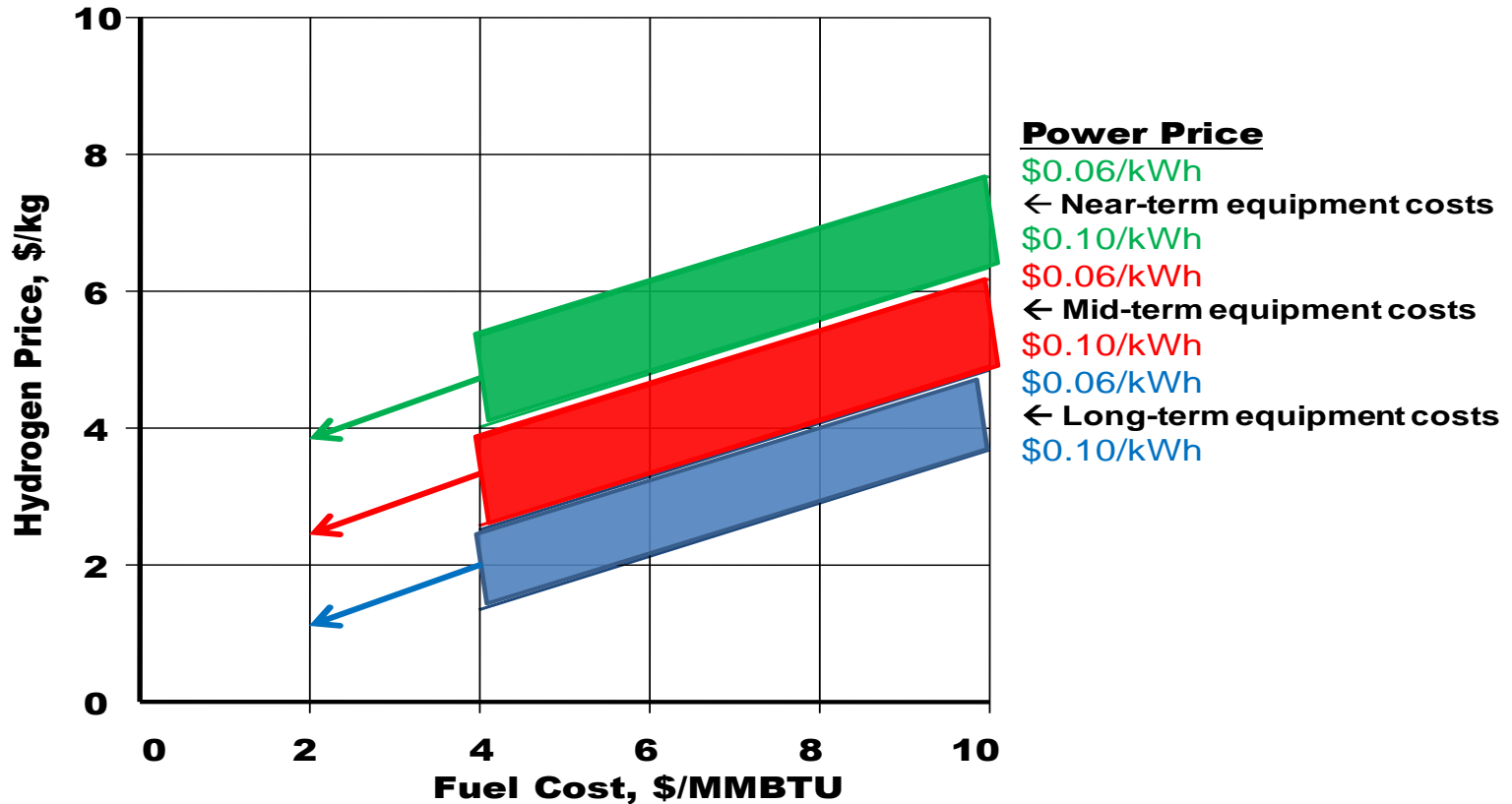
- Tri-gen scale-up to MW scale modular system (building block)
- Solid state H₂ separation technology scale-up to commercial capacity
- Power management system for 2-way communication with grid
- Manufacturing development of integrated energy storage system
- **Demos for grid support at multiple manufacturing sites**

Thank You!

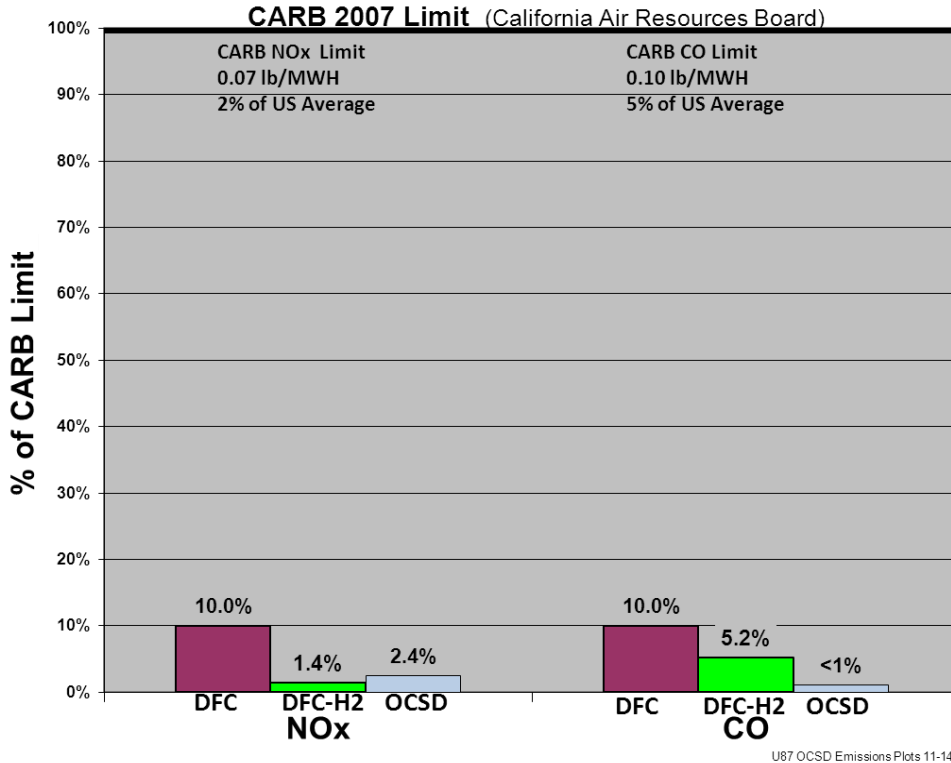
Sponsors:



Contact: ppatel@fce.com



Revenue from power reduces cost of on-site hydrogen production



Need guidance from CA EPA

At 5,000 MWh

NOx Emissions 0.03% of US Ave
20,000 lbs typical emissions (4.2 lb/MWh)
5 lbs emitted

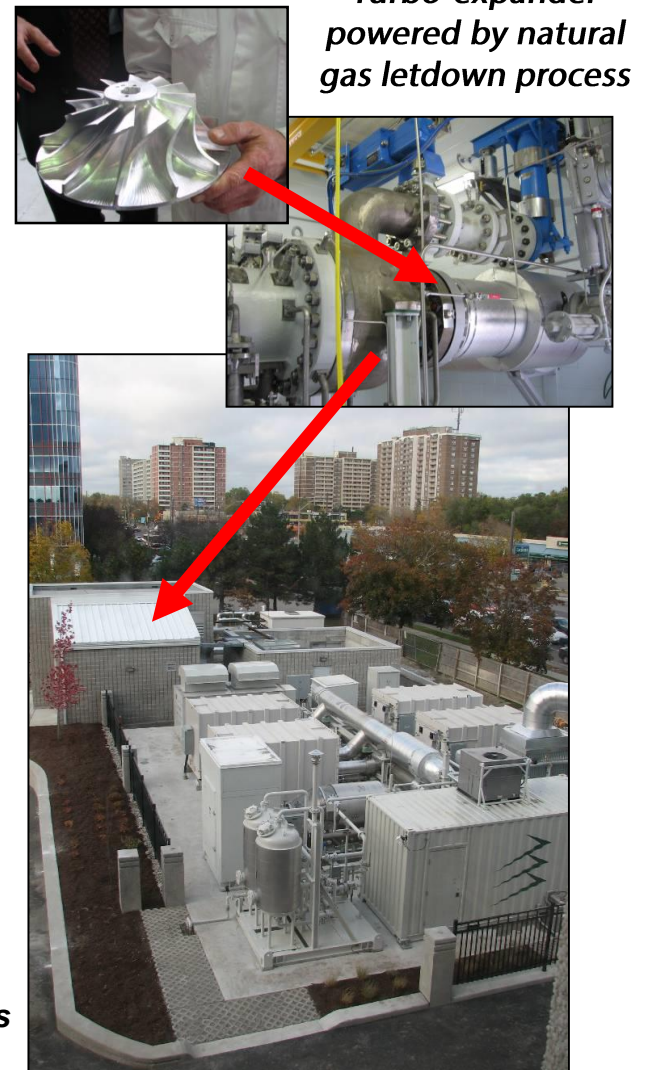
Value = 20 - 100,000 \$/ton
\$1,000,000

SOx Emissions ~ Zero
46,000 lbs typical emissions (9.2 lb/MWh)
<5 lbs emitted

Value 5 – 50,000 \$/ton
\$1,150,000

Over 2 million \$ in environmental benefits

- **DFC-ERG (Direct FuelCell Energy Recovery Generation™) for pipeline letdown operations**
 - Energy from pressure letdown fed to turbine
 - Byproduct heat warms gas to prevent freezing
 - Excess electricity sold to the grid
- **High efficiency**
 - 62% avg. electrical efficiency/70% peak efficiency
- **Compelling value proposition for gas companies**
 - Attractive economics
 - Virtual absence of pollutants & low CO₂ emissions



Preferred Resource: Examples



Grid support, with CHP



Grid support benefitting urban redevelopment



University Micro-grid, with CHP



Fuel cell / Solar integration