

*2021 LEAP Workshop –
Pathways to Commercialization*

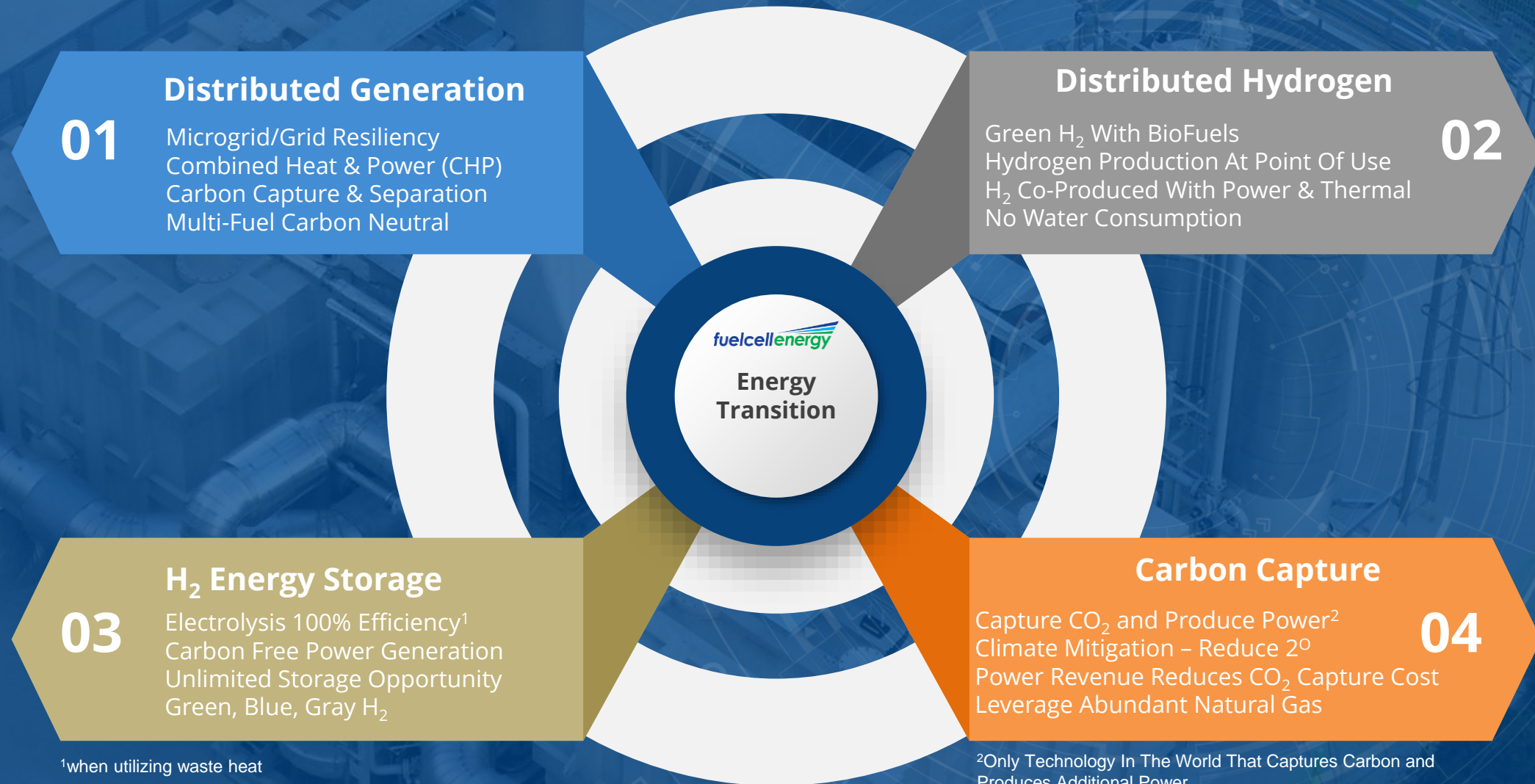


High Temperature Fuel Cell Technology for the Energy Future

Michael Pastula, M.A.Sc., P. Eng.
Senior Manager, Engineering
Calgary, Alberta Canada



FuelCell Energy Clean Technologies Transforming 4 Major Energy Opportunities



Fuel Cells for Distributed Generation

Grid Support with CHP

- Power sold to grid
- Heat sold to district heating system
- 20 MW KOSPO site built in 2018
- 6 month construction time
- Potential to easily scale larger



Grid Support / Urban Redevelopment

- Power sold to grid
- Enhance resiliency
- Brownfield revitalization
- 15 MW on 1 ½ acres
- Only 12 mo. Installation
- Owned by FuelCell Energy

Resiliency for Pharma

- 5.6 MW with steam for company campus
- Predictable power solving grid quality issues
- Immediate savings vs. grid
- Sustainability



Fuel Cell / Solar Integration

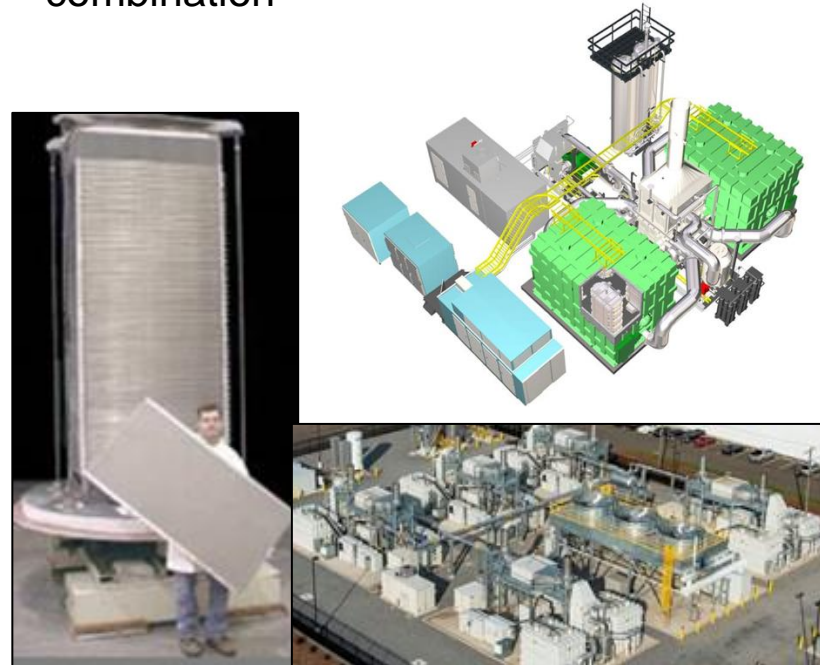
- Utility-owned, rate-based
- Enhance resiliency
- 2.8 MW fuel cell on ¼ acre
- ~23,000 MWh annually
- 2.2 MW solar on ~9 acres
- ~3,000 MWh annually

High Temperature Fuel Cell and Electrolysis Solutions

- Fuel cells cleanly and efficiently convert energy in hydrogen rich fuels into electricity and high-quality heat
- A fuel cell stack is comprised of many individual cells grouped together. Stack modules can have one or more stacks
- Fuels are converted to hydrogen in the stack by reforming using water and heat produced by the fuel cells
- Hydrogen not used in power generation can be exported to hydrogen users
- Fuel cell stacks can also operate in electrolysis mode – producing hydrogen from steam and power

Carbonate

- Large stacks provide economies of scale in MW-scale power generation applications
- Uniquely suited to operate with on-site renewable biogas
- Produces hydrogen through internal reforming or electrolysis/reforming combination



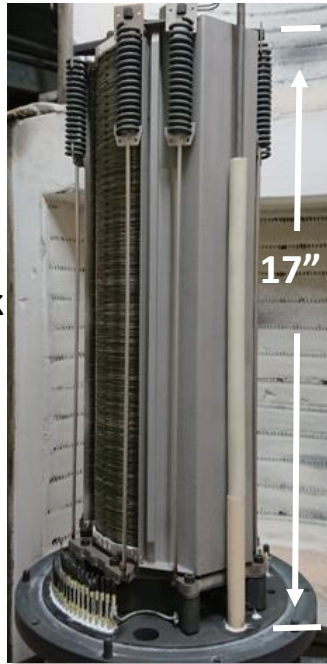
Solid Oxide

- Compact, lightweight and scalable stack design
- Can operate with natural gas, biogas, or hydrogen fuel
- Can produce hydrogen through internal reforming or electrolysis
- Can alternate between fuel cell and electrolysis modes in hydrogen-based energy storage systems

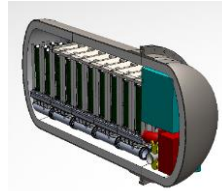


Solid Oxide Applications

SOFC Stack

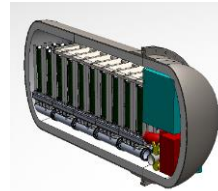


7 kW DC Power Generation
36 kW DC / 25 kg H₂/day electrolysis
350 cells, 17" height



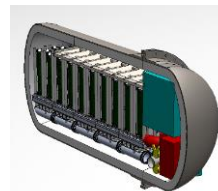
Power Generation Stack Module

Only runs in power generation mode on a wide range of fuels, including natural gas, biofuels, propane, and hydrogen



Electrolysis Stack Module

Produces hydrogen from steam with power input

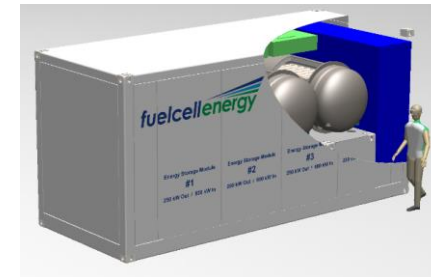


Energy Storage Stack Module

Alternates between power generation on hydrogen fuel & electrolysis producing hydrogen from water



200kW Power Generation System
Sub-MW / SOFC-GT Hybrid



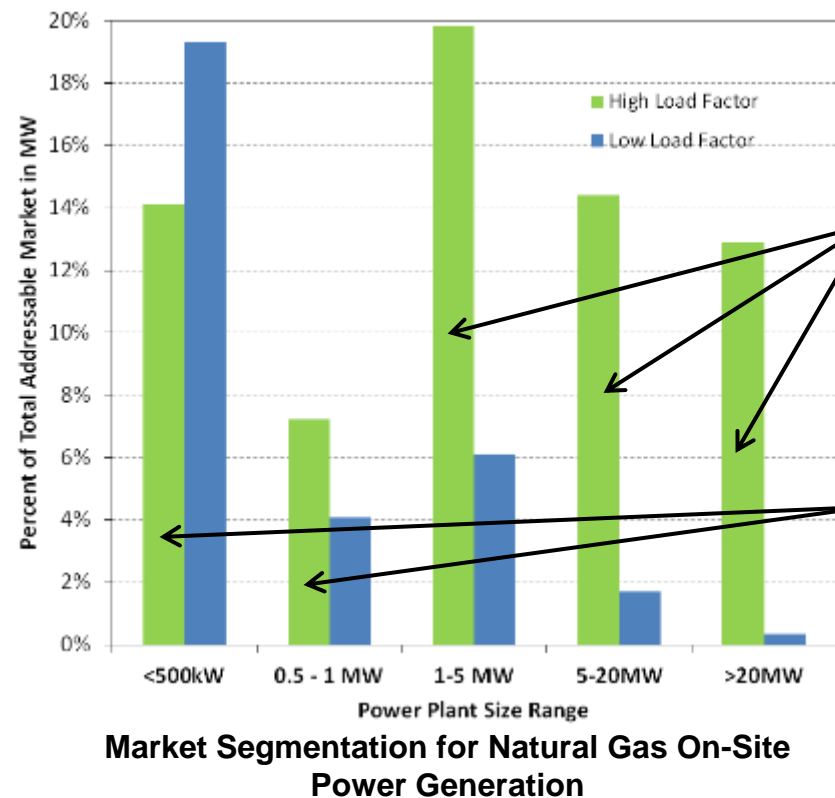
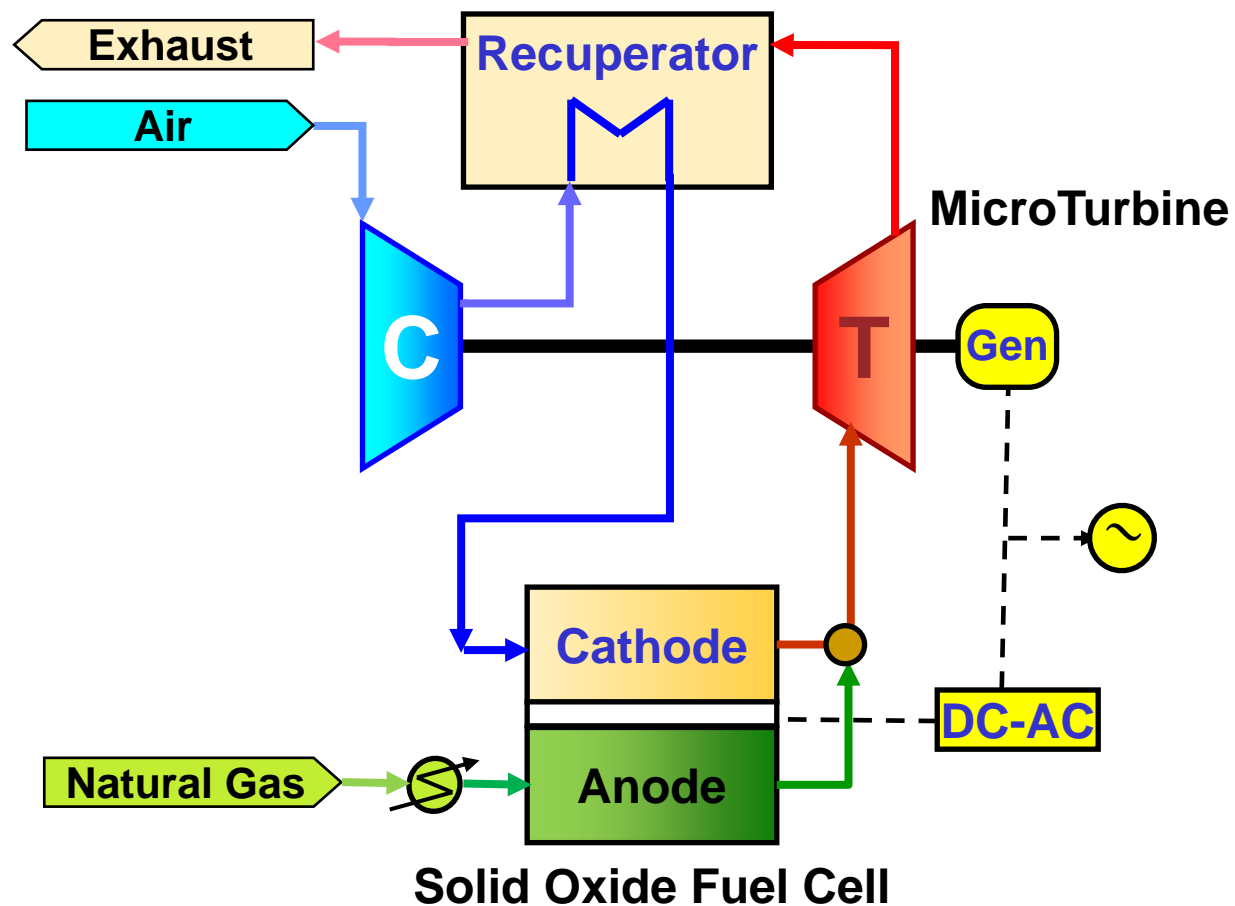
Electrolysis
4,000 kg/day H₂ from 7.3 MW



Energy Storage System
1MW 8 MWh

Versatile platform with multiple commercialization paths

INTEGRATE Adaptive SOFC - GT Hybrid for Ultra High Efficiency



- Long-term high load factor > 1MW
Near term market is \$6 B

- Near-Term high load factor, <1MW
Near term market is \$1.5 B

Data Source: "Combined Heat and Power Market Assessment", ICF International, Inc; Prepared for California Energy Commission Public Interest Energy Research Program; October 2009; CEC-500-2009-094-D

>70% LHV Electrical Efficiency on Natural Gas with up to 70% H₂ (/volume) Fuel Flexibility

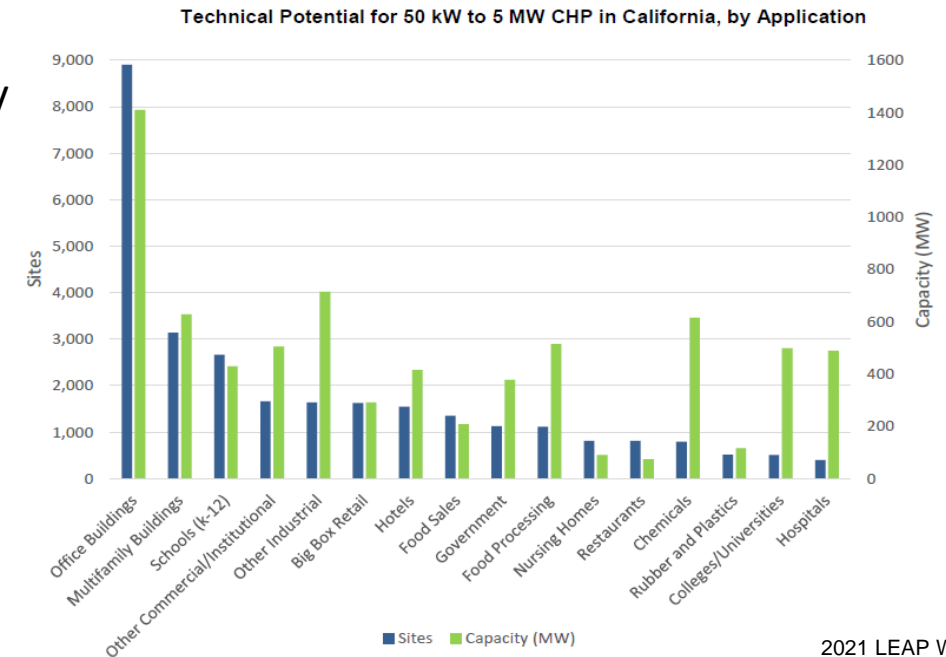
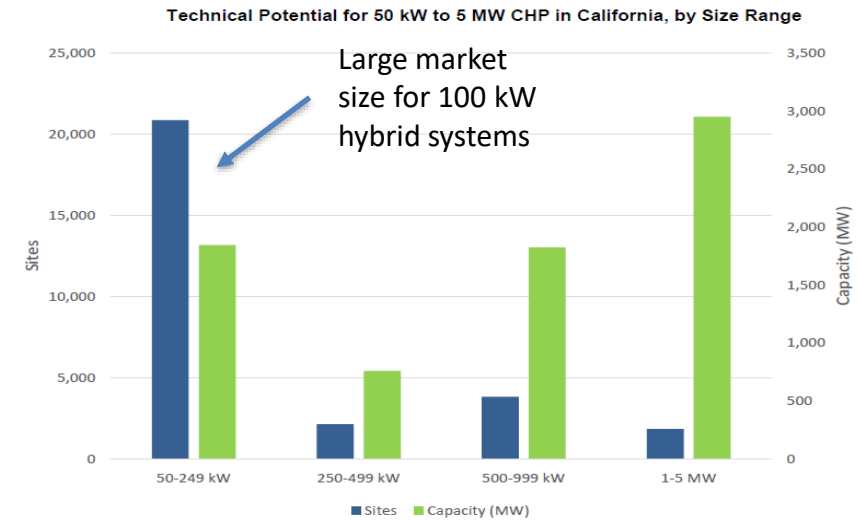
Adaptive SOFC- GT Hybrid Market Applications

Low cost and ultra high efficiency systems using adaptive SOFC combined with other power cycles provide a superior alternative for distributed electricity generation in near term markets:

- On-site / Micro-grid
- Grid-support

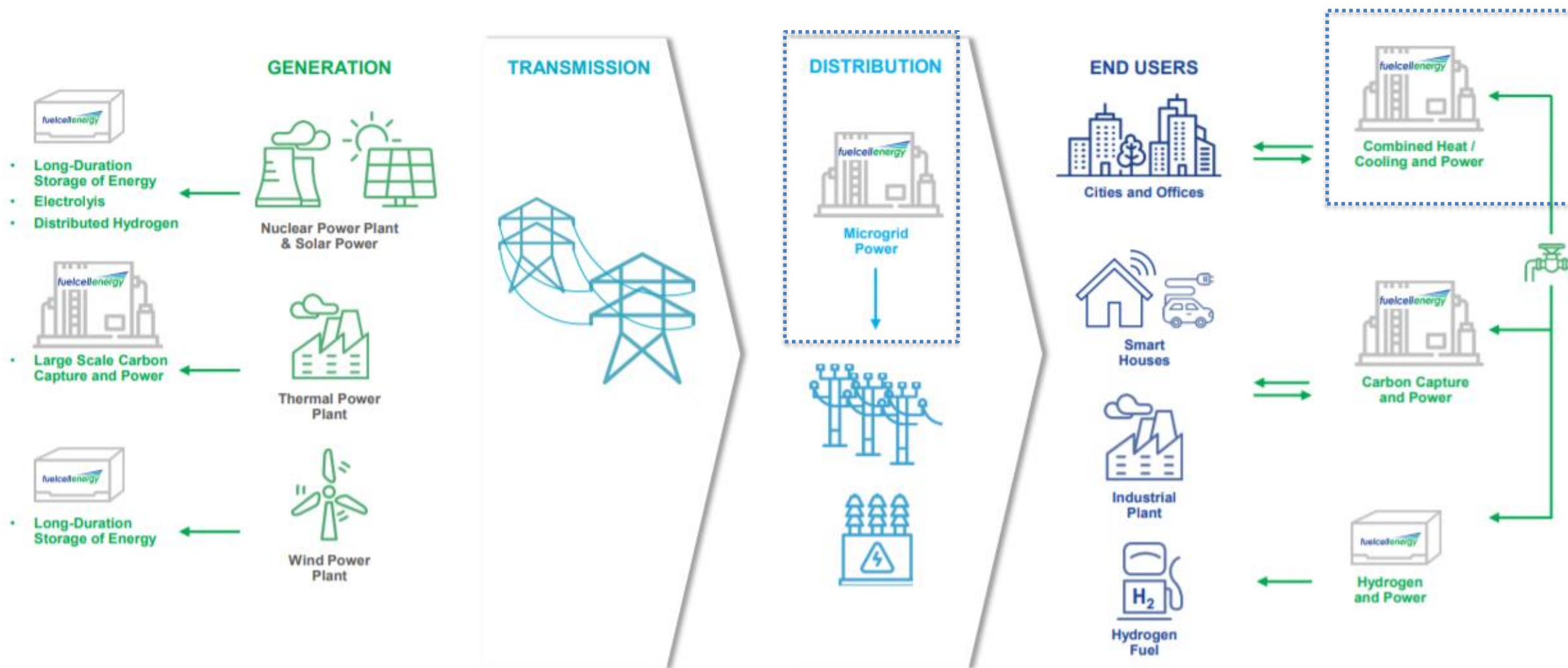
Examples:

- Utility/Gas companies and energy providers such as SoCal Gas/ Southern California Edison
- Premium power users such as data centers
- Digester gas produced from municipal water treatments comprised of a large market size, e.g.:
 - over 20,000 sites in Europe
 - California initiatives for installing digesters for small farm waste management



Positioned to Serve the Evolving Energy Grid with Current & In-Development Platforms

A growing source of clean, reliable power for microgrid, Carbon Capture, electrolysis and Hydrogen Energy Storage



Thank You

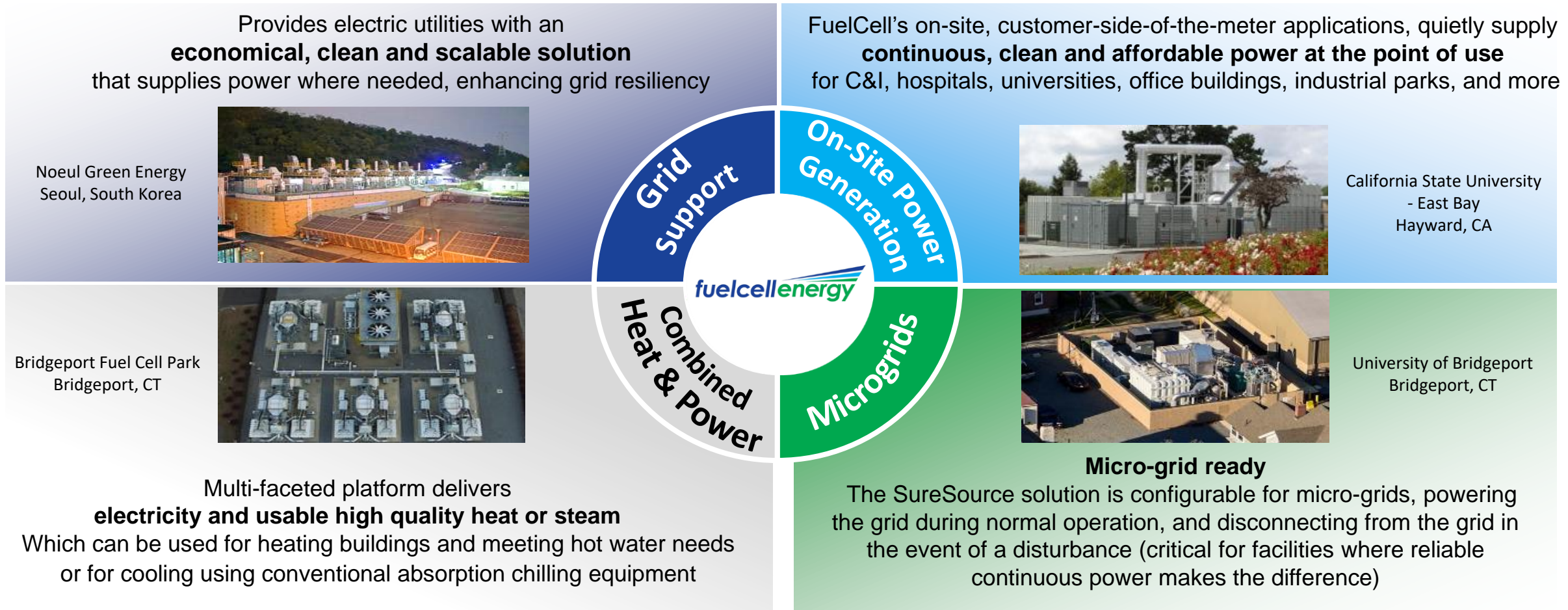
**Enable The World
To Live A Life
Empowered By
Clean Energy**








fuelcellenergy

Fuel Cells for Distributed Generation

FuelCell's technology has been successfully deployed in these applications:



Building on Multi-Featured Current Strengths with Next-Gen Technologies

	DISTRIBUTED GENERATION	DISTRIBUTED HYDROGEN & CARBON SEPARATION*	HYDROGEN & ENERGY STORAGE	CARBON CAPTURE
INDUSTRY APPLICATION	<ul style="list-style-type: none"> Enabling microgrid power generation Local generation reducing above ground risk Improving the climate and air quality in local communities \$1.1B of project backlog as of July 31, 2021 	<ul style="list-style-type: none"> Building hydrogen distribution platform in Long Beach to support Toyota's operations to fuel zero emission FCEV's and provide clean water Will Enable hydrogen transportation No pipeline infrastructure needed 	<ul style="list-style-type: none"> Working to advance FuelCell Energy reversible solid oxide technology, with support from the US Department of Energy, that will support the technology for electrolysis and energy storage applications 	<ul style="list-style-type: none"> Joint development agreement with ExxonMobil Research and Engineering Company (EMRE) Unique carbon capture technology that captures carbon while producing power
SOLUTION				 
STATUS	In Operation	Commercially Available	Advanced Development	Developing with EMRE
<div>Today</div> <div>2022+</div>				
ADDITIONAL APPLICATIONS ENABLED THROUGH OUR TECHNOLOGY PLATFORM	<ul style="list-style-type: none"> Carbon separation to support industry, such as beverage, agriculture and more 	<ul style="list-style-type: none"> Natural gas blending to reduce carbon Hydrogen to repower gas engines 	<ul style="list-style-type: none"> Highly efficient electrolysis Hydrogen power generation 	<ul style="list-style-type: none"> Mitigating climate change

Long-term Macro Trends Supporting Clean Energy



Sustainable Clean Energy

Renewable energy exceeded coal for the first time by providing 23% of U.S. power generation, compared to coal's 20% share¹ in April 2019

Broader shift towards consumption of clean energy/power generation



Grid Resiliency and Reliability

Intermittency of power resources, natural disasters, and events such as the California fires have increased public awareness of grid limitations

FuelCell Energy's on-site power generation solutions are ideal for installations requiring continuous 24/7 power such as hospitals, schools, and large businesses



Carbon Reduction

Paris Climate Agreement: global economies committed to become carbon neutral by 2050

FuelCell Energy has the only technology in the world that produces power while capturing carbon



Regulatory Support

Energy leaders are supporting policies and incentives that enable the commercialization of fuel cell and hydrogen technologies as low impact and high confidence solutions

FuelCell Energy supports the environmental objectives of local, regional and national governments

Fuel Cell Technology Well Positioned to Meet Growing Demand