

FuelCell Energy: Tri-gen Project at Toyota Logistic Services Port of Long Beach



FuelCell Energy: a global leader in fuel cell technology

OPERATING SINCE 1969

FuelCell Energy is a global leader in decarbonizing power and producing hydrogen through our proprietary fuel cell technology

FuelCell Energy is working to:

- **Produce** low- to zero-carbon power
- **Capture** carbon and greenhouse gasses while simultaneously generating power
- **Supply** green or blue hydrogen energy
- **Store** energy from intermittent renewables by converting excess power to hydrogen – then converting back into power when it’s needed or delivering to other applications

- **Danbury, CT, USA**
Corporate headquarters
- **Torrington, CT, USA**
Carbonate manufacturing
- **Taufkirchen, Germany**
Assembly & service
- **Calgary, Canada**
Solid oxide R&D/manuf.

COMPANY HIGHLIGHTS

HQ Danbury, Connecticut

>500 Employees

95 Platforms in Commercial Operation

3 Continents

FCEL Listing: NASDAQ

>225 MW Capacity in Field

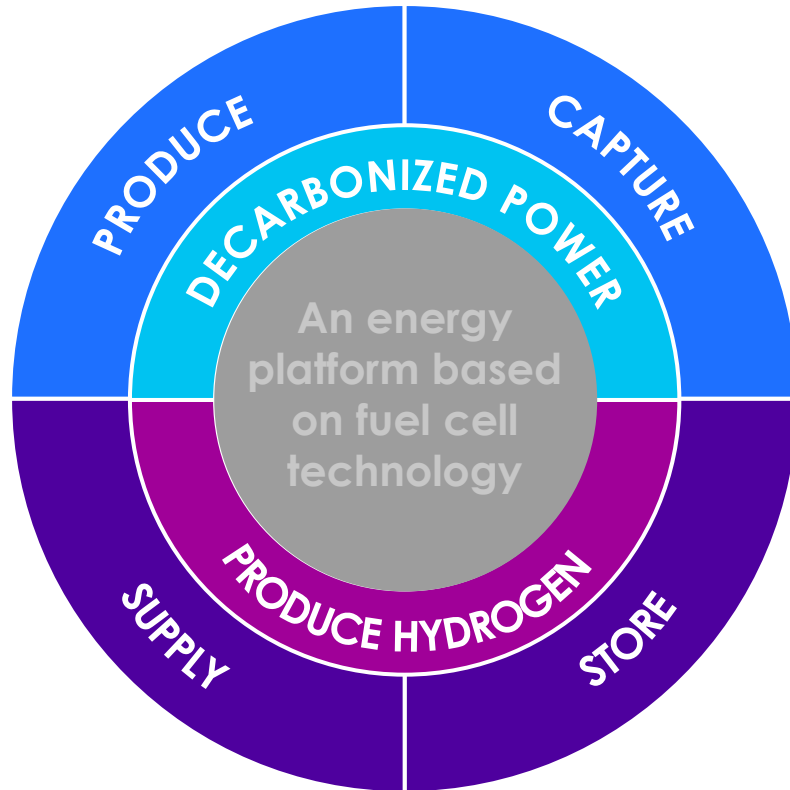
>15 Million MWhs generated with SureSource patented technology

GLOBAL CUSTOMERS



Our Purpose: Enable a World Empowered by Clean Energy

ENABLING A SAFE, SECURE AND PRACTICAL JOURNEY
TO CARBON ZERO



OUR PLATFORM EMPOWERS A SAFE, SECURE AND
PRACTICAL JOURNEY TO CARBON ZERO

DECARBONIZING POWER



- Produce decarbonized power
- Capture carbon and greenhouse gases at low cost with the ability to generate power and hydrogen at the same time
- Negligible nitrogen oxide (NOx) and sulfur oxide (SOx) emissions

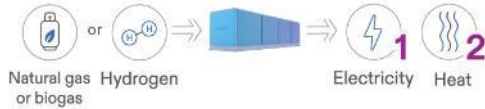
PRODUCING HYDROGEN



- Supply green hydrogen (using electrolysis of water or reforming of biogas) or blue hydrogen power (using natural gas with carbon separation or carbon capture) with high efficiency
- Working to commercialize a solution that scales renewables by converting excess power to hydrogen – then converting hydrogen back to power when needed
- Ensuring people and industry continue to have access to reliable and affordable energy as the industrialized world continues to move forward by supporting our hardest to decarbonize sectors
- Working to commercialize a gigawatt scalable solution that supports the intermittency of renewables by converting excess power to hydrogen – then using that hydrogen to make zero carbon power

Where do fuel cells make sense?

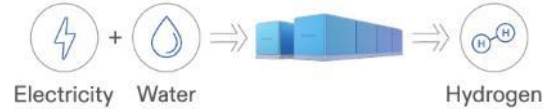
1 Power Generation



- ✓ Ideal for baseload power applications especially in power constrained regions
 - ✓ Usable waste heat increases site efficiency and lowers OPEX
- ✓ Competitive where energy prices >\$0.12/kWh Reduces/eliminates demand charges
- ✓ Provides fuel flexibility: natural gas, biofuels, propane, and hydrogen
- ✓ Fuel cells do not require special air permits.
- ✓ Non-combustion. Eliminate NO_x or SO_x pollutants



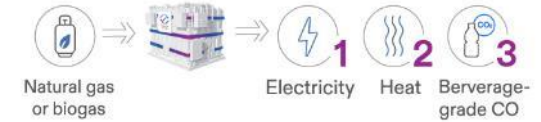
2 Hydrogen Production



- ✓ 600 kg/day H₂ from 1.1 MW (1 MW with thermal input)
- ✓ FCE provides lowest levelized cost of green H₂
- ✓ 90% electrical efficiency (100% with thermal input)
- ✓ Use for distributed, on-site H₂ fueling or large scale H₂ plants



3 Onsite CO₂ Recovery



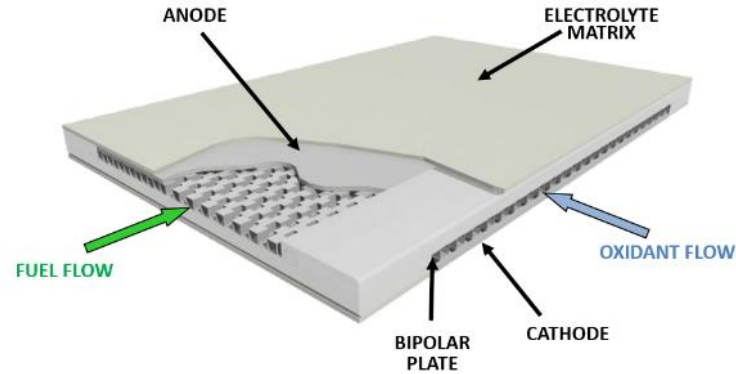
- ✓ Provide competitive, steady supply of CO₂ to support local operations
- ✓ Usable heat (3.82 MMBtu/h) to offset boiler fuel and load
- ✓ Decarbonize sites by capturing other on-site flue gas streams



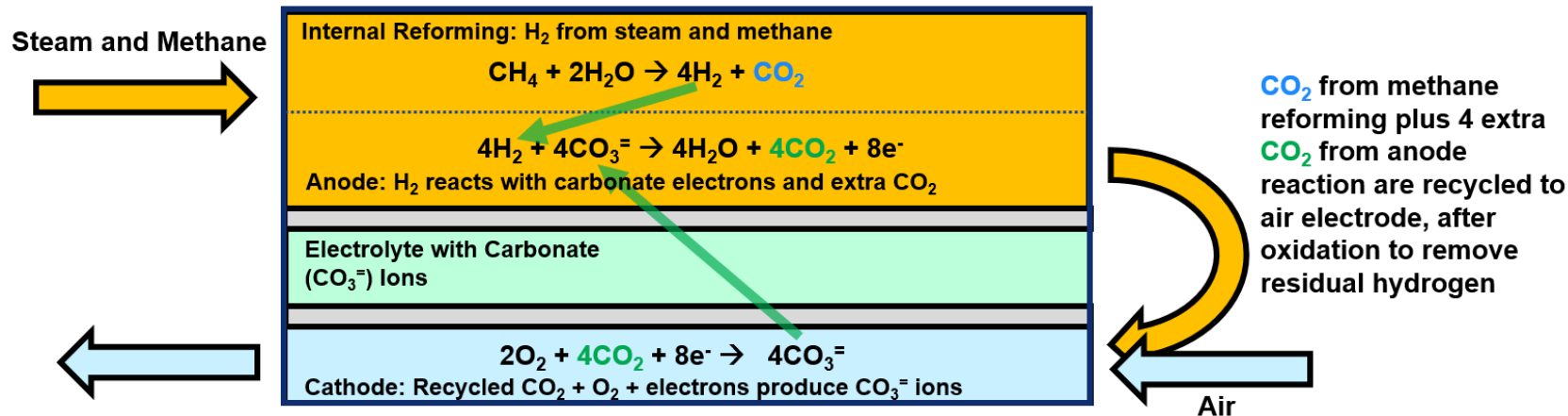
Finance options: Capital Purchase, Power Purchase Agreement (PPA), Lease.
In all options, FCE provides long term service agreement to operate and maintain the systems.

Carbonate Power Generation Solutions

Carbonate fuel cell operating principle



- Efficient conversion of methane fuel to hydrogen in the stack drives high efficiency and provides the opportunity for hydrogen export
- SureSource carbonate fuel cell electrochemistry involves transfer of CO_2 from cathode (air electrode) to anode (fuel electrode)
- This aspect can be exploited to use carbonate stack for CO_2 separation, with concentration in anode gas allowing for easy capture and use or sequestration



Carbonate power generation platforms



400-cell fuel cell
stack package



Four-stack
module
1.4MW



1.4 MW net power
47% electrical efficiency
up to 90% total efficiency



2.8 MW net power
47% electrical efficiency
up to 90% total efficiency



Tri-generation
2.35 MW net power
1,270 kg/day hydrogen
1,400 gal/day water



Carbon Recovery
1.3-1.8 MW power
20+ Mt/day CO₂



14 MW (Derby, CT)



15 MW (Bridgeport, CT)



59 MW (Korea)

Large-scale fuel cell parks

Global track record of reliable power generation

Grid Support with CHP

- 20 MW site built in 2018
- Power sold to grid
- Heat sold to district heating
- 6 month construction time
- Easily scalable



Grid Support / Urban Redevelopment

- 15 MW on 1.5 acres
- Power sold to grid
- Enhanced resiliency
- Brownfield revitalization
- 12 mo. Installation



Resiliency for Pharma

- 5.6 MW w/steam for company campus
- Reliable power solving local grid instability
- Immediate cost savings
- Complements ESG goals



Fuel Cell / Solar Integration

- 2.8 MW fuel cell on ¼ acre
- 2.2 MW solar on ~9 acres
- Utility-owned, rate-based
- Enhanced resiliency



MORE THAN 15 MILLION MWH GENERATED BY CARBONATE POWER PLATFORMS

Extensive on-site biogas experience



City of Riverside (1.4 MW)

The SureSource 1500™ fuel cell plant cleans and consumes renewable biogas from the wastewater treatment process to generate carbon-neutral power and heat for the facility.

- 24/7 power profile
- Limited capital costs
- Heat supports anaerobic digesters



San Bernardino (1.4 MW)

The SureSource 1500™ fuel cell plant supports the City of San Bernardino Municipal Water Department using anaerobic digester gas (ADG) and supplemental natural gas as needed.

- Carbon-neutral power
- Heat support anaerobic digesters
- Biogas cleaned with FCE conditioning system



Tulare (2.8 MW)

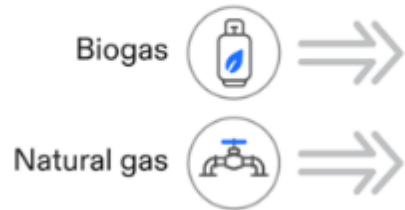
The SureSource 3000™ fuel cell system is fueled by the City's biogas which is treated using the SureSource Treatment™ fuel cleaning system.

- Carbon-neutral power
- Now uses biogas instead of flaring it
- Benefits from the state's BioMAT program

We have more than 500,000 operating hours of experience from decades of biogas-fueled projects

Carbonate Tri-gen for Hydrogen Production

Carbonate Tri-gen sustainability benefits



2.35 MW Clean and renewable power – 18 GWh/year

- 1200 tons per year avoided grid CO₂ emissions with natural gas fuel
- 10,000 tons per year avoided grid CO₂ emissions with biogas fuel
- 5 tons per year avoided NOX

0.5 MMBtu/h thermal energy

- 290 tons per year avoided boiler CO₂ emissions
- 200 lbs per year avoided NOX

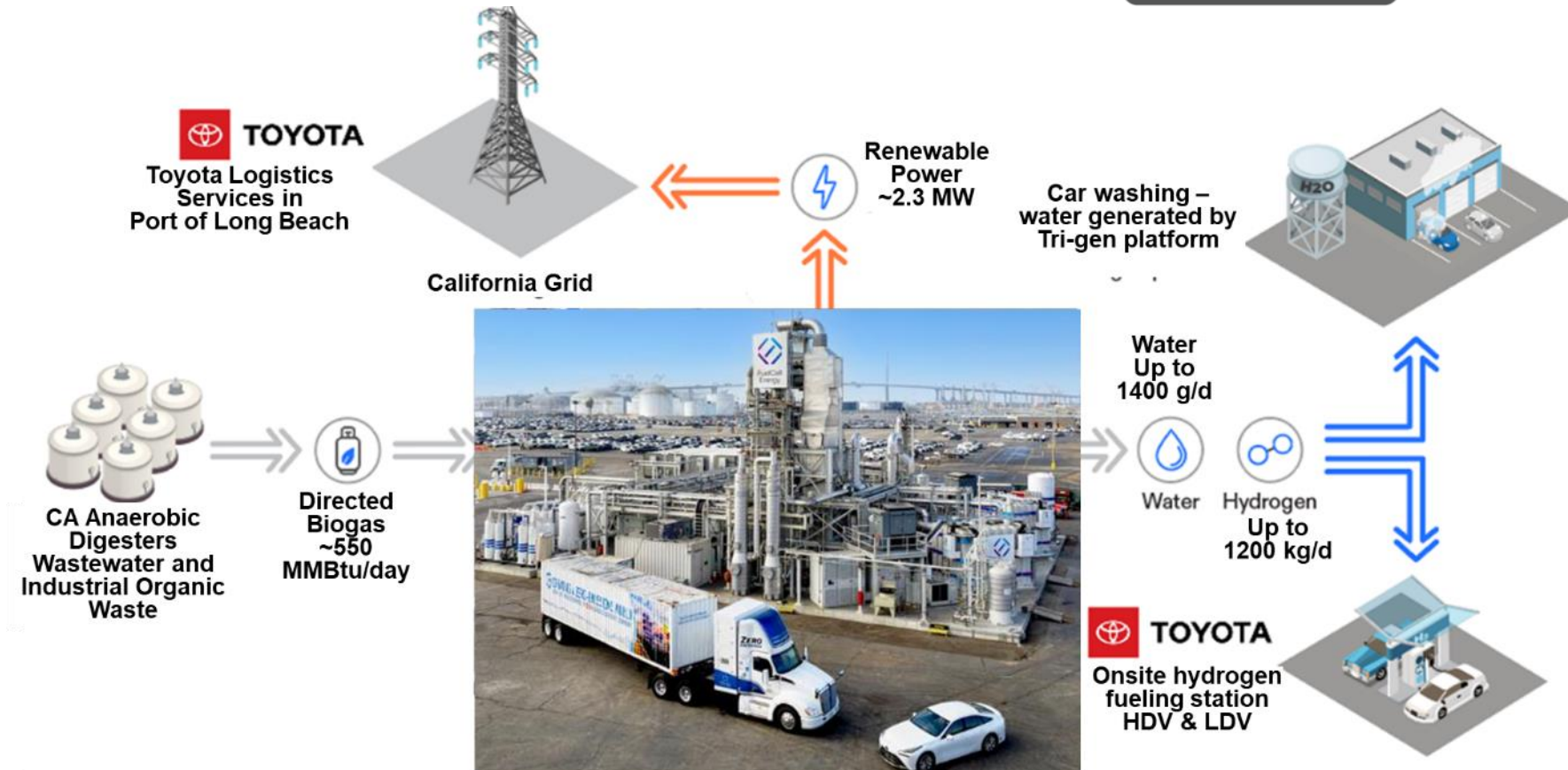
1270 kg/day hydrogen

- 1700 tons per year CO₂ reduction vs SMR
- 4200 tons per year CO₂ reduction vs SMR with biogas fuel
- 700 lbs per year NOX reduction vs SMR
- 2 million gallons less water used per year vs SMR

1400 gallons / day water

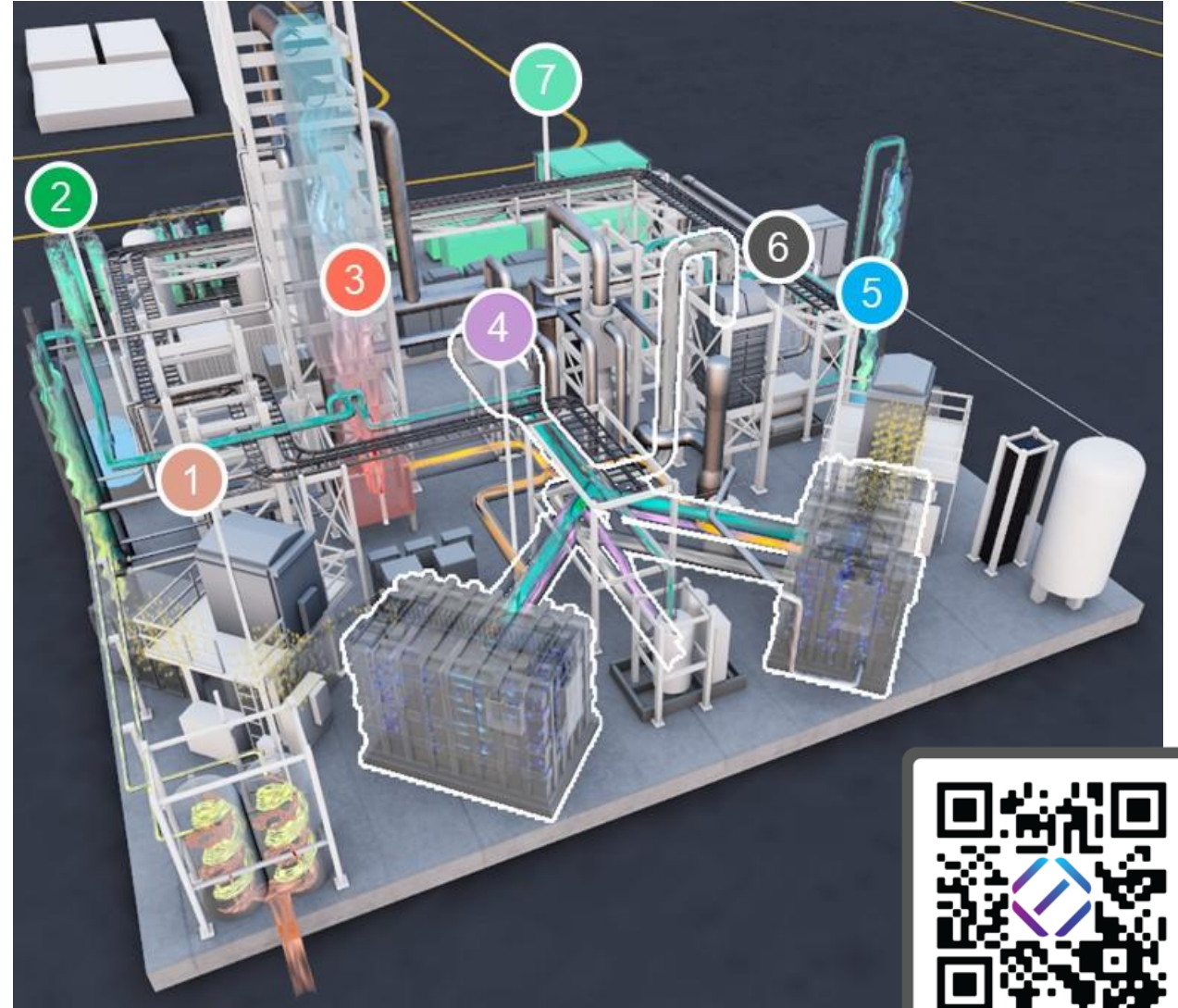
Tri-gen: How it works

- Hydrogen production from methane reforming using fuel cell heat and water during power co-production
- Compared to conventional steam methane reforming (SMR):
 - No fuel combustion for process heat
 - No water consumption
- Avoided combustion emissions, lower CO₂
- The system produces up to:
 - 2.3MW of electricity
 - 1200 kg of hydrogen/day
 - 1400 gallons of water/day



Tri-gen process components overview

1. **Inlet:** Directed biogas from adjacent pipeline
2. **Gas saturation:** Wetting gas to ideal water/methane ratio for reforming
3. **Pre-heating:** Via fuel cell stack exhaust waste heat
4. **Fuel cell reforming:** Heat and water from fuel cell power generation used to reform gas to produce H₂
5. **Power generation:** From fuel cell, inverted from DC to AC
6. **Water recovery:** Cooling of gas leaving fuel cell for water vapor recovery and re-use
7. **Hydrogen purification:** H₂ purified to SAE specification for fuel cell vehicle use
8. **Offtake:** Hydrogen dispensing at vehicle refueling station.



3D Tour

Tri-gen on-site biogas application



- Operation with on-site biogas may be best value proposition
 - Low-cost renewable fuel
 - Minimal fuel upgrading required since carbonate can operate on dilute biogas
 - Co-production of power, heat, and water supports water treatment facility operation
 - FCE has extensive experience in biogas processing and on-site biogas power projects at wastewater treatment plants and breweries
- The first demonstration of Tri-gen was at the wastewater treatment plant of Orange County Sanitation District in Fountain Valley, CA using on-site biogas with on-site hydrogen filling station

Tri-gen Photos

Tri-gen at Toyota Logistic Services (TLS)

Generating renewable electricity with renewable natural gas
Delivering hydrogen to Shell station for light duty Mirai's and heavy duty trucks



Tri-gen at Toyota Logistic Services (TLS)

Generating renewable electricity with renewable natural gas
Delivering hydrogen to Shell station for light duty Mirai's and heavy duty trucks















Thank You

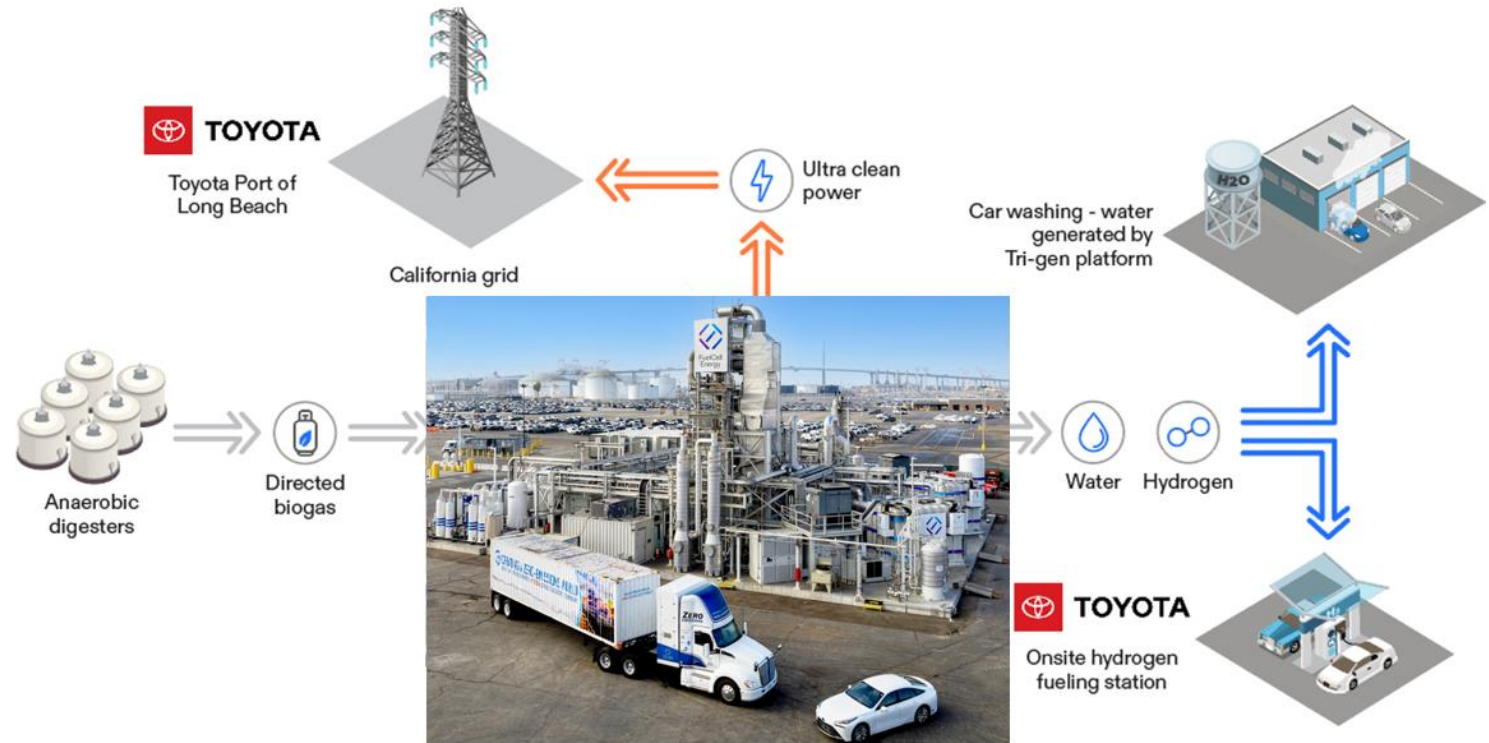


FuelCell Energy contact: Paul Fukumoto pfukumoto@fce.com 949.636.9746

Tri-gen Supplemental Information

Tri-gen: How it works

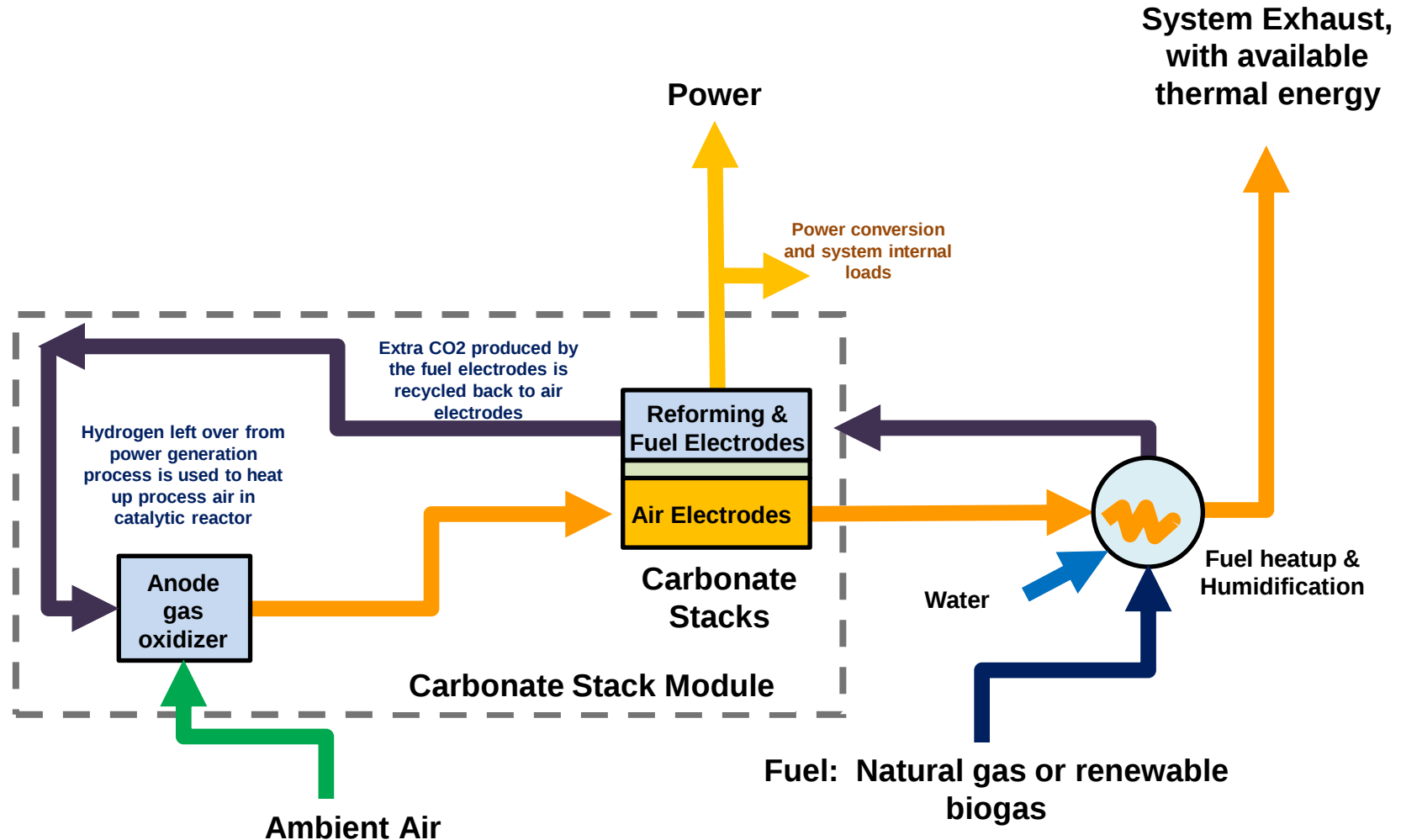
- Hydrogen production from methane reforming using fuel cell heat and water during power co-production
- Compared to conventional steam methane reforming (SMR):
 - No fuel combustion for process heat
 - No water consumption
- Avoided combustion emissions, lower CO₂
- The system produces up to:
 - 2.3MW of electricity
 - 1200 kg of hydrogen per day
 - 1400 gallons of water per day



Carbonate fuel cell process overview

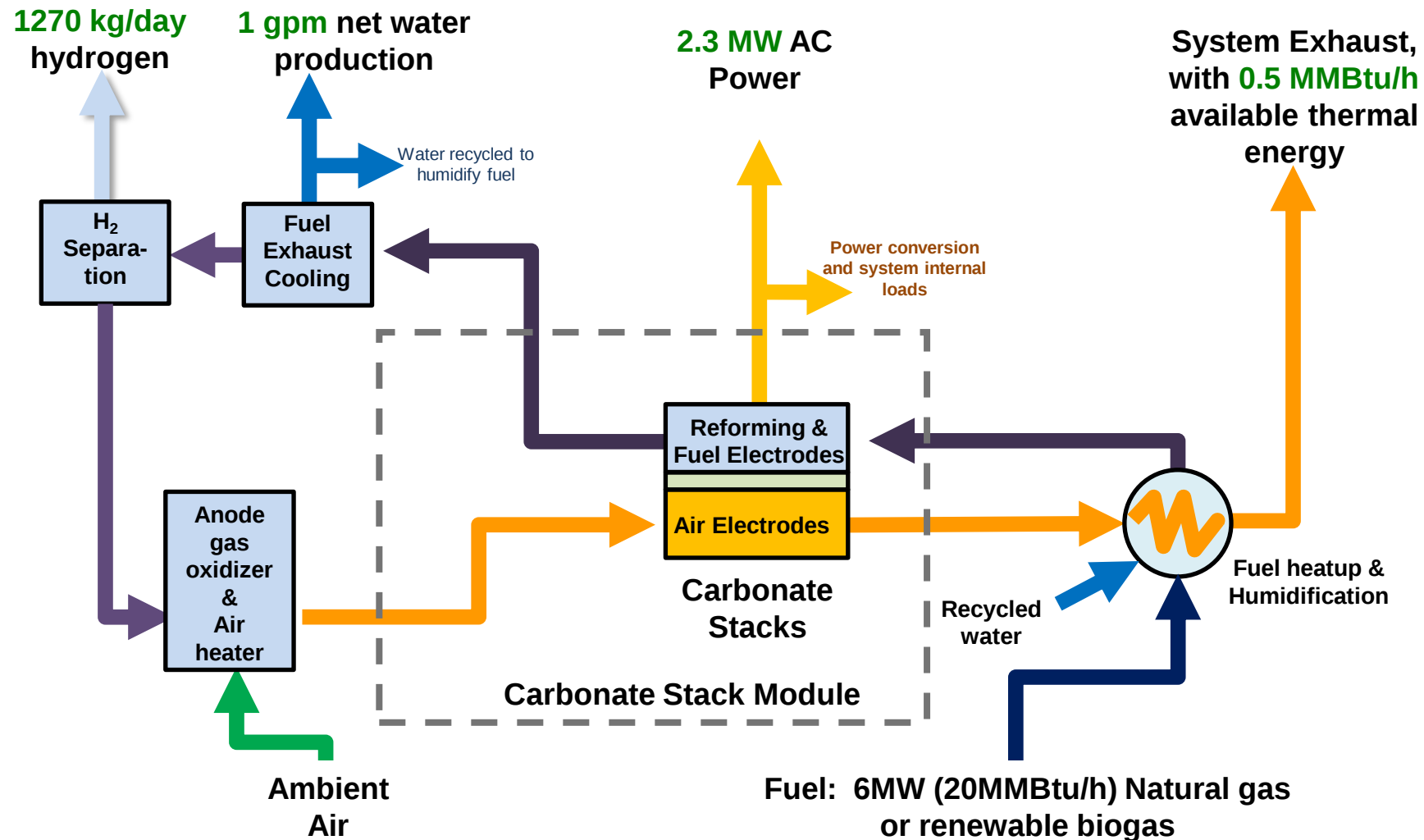


The carbonate stack module includes four stacks, ducting, and the anode gas oxidizer



Hydrogen is produced from internal reformation of methane-based fuel, and used to make power and heat process air for fuel cell reaction

Carbonate Tri-gen process overview



The entire anode exhaust stream is extracted from each 1.4MW module, which no longer has an internal anode gas oxidizer. The gas is processed to remove hydrogen, and then returned to the modules

Tri-gen added balance of plant equipment

Added equipment
beyond standard
carbonate BOP:

Air to air heat
exchanger for air
pre-heat

Equipment to cool
and dry anode
exhaust

Equipment to
extract and purify
 H_2 from anode
exhaust



<https://polb.com/port-info/news-and-press/renewable-energy-project-powers-port-with-hydrogen-05-02-2024>

