

DOE's H2@Scale Initiative and Biogas Projects

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LMOP Special Session

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An exciting time for the transportation sector



Honda Clarity

Approximately **6,400** | **sold or leased**
in the United States



As of Dec 2017

Hyundai Tucson Fuel Cell SUV

Commercial fuel cell electric cars are here



Toyota Mirai

- ✓ No petroleum, no pollution
- ✓ Refuels in minutes
- ✓ More than 360 mi driving range
- ✓ Over 60 mpgge

Long-Range, Heavy Duty Applications Emerging



Fuel cell delivery and parcel trucks starting deliveries in CA and NY




>2,000 fuel cell buses planned for deployment worldwide


>13,000 heavy duty fuel cell trucks ordered in the U.S. to date





Applications and Funding of Hydrogen and Fuel Cells


Examples of Application in the United States

- 

Over **>240MW**
Backup Power
- 

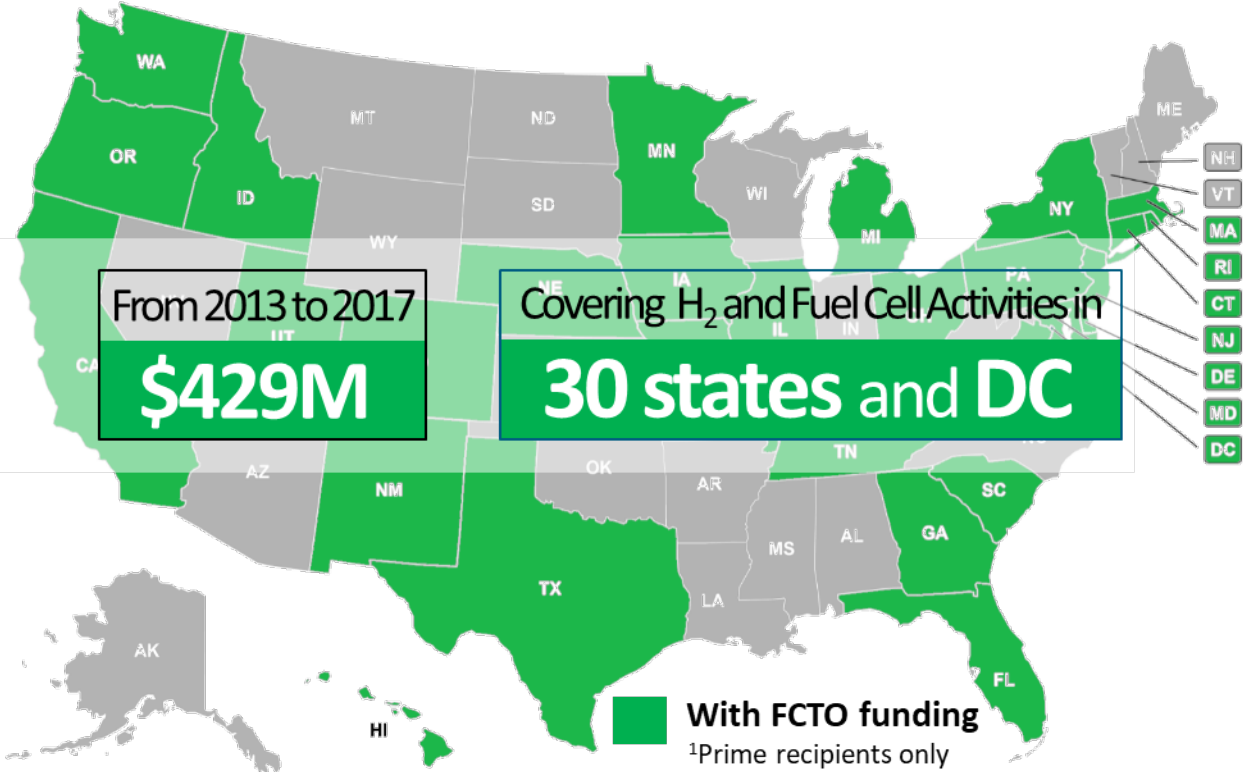
More than **>23,000**
Forklifts
- 

More than **>30**
Fuel Cell Buses
- 

~40
H₂ Retail Stations
- 

Over **6,400**
Fuel Cell Cars

EERE Fuel Cell Technologies Office Funding¹ FY 2013 – FY 2017



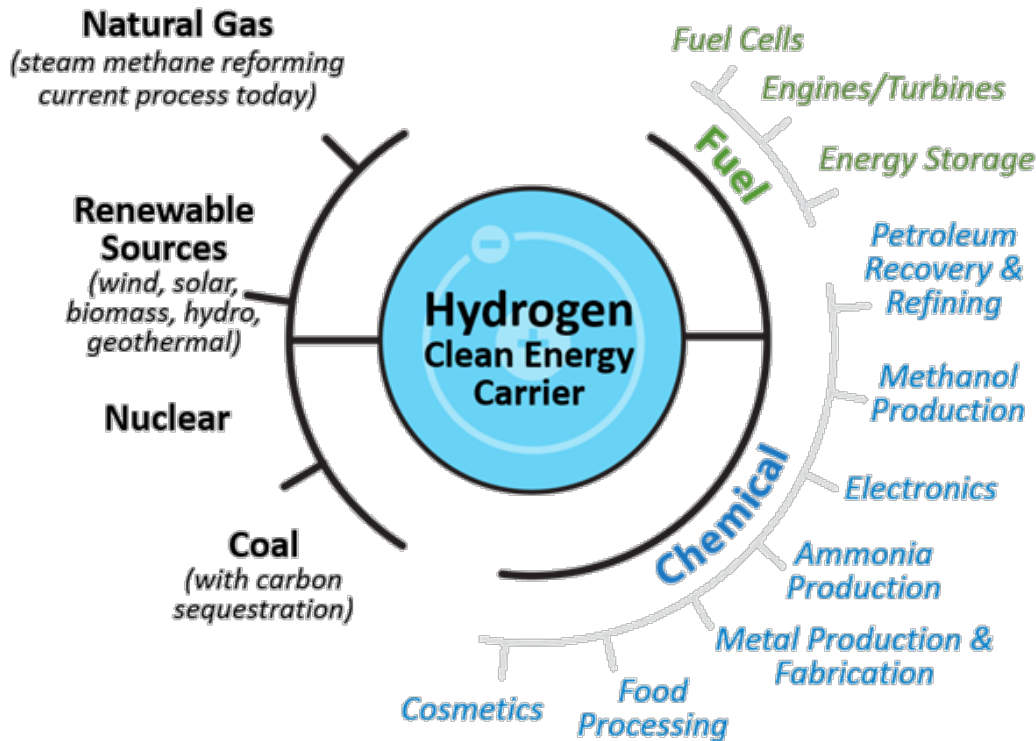
Hydrogen Stations: Examples of Plans Across States

- California**
1,000 stations by 2030
- Northeast**
12 – 20 stations planned
- HI, OH, SC, NY, CT, MA, CO, UT, TX, MI, and others**
with interest

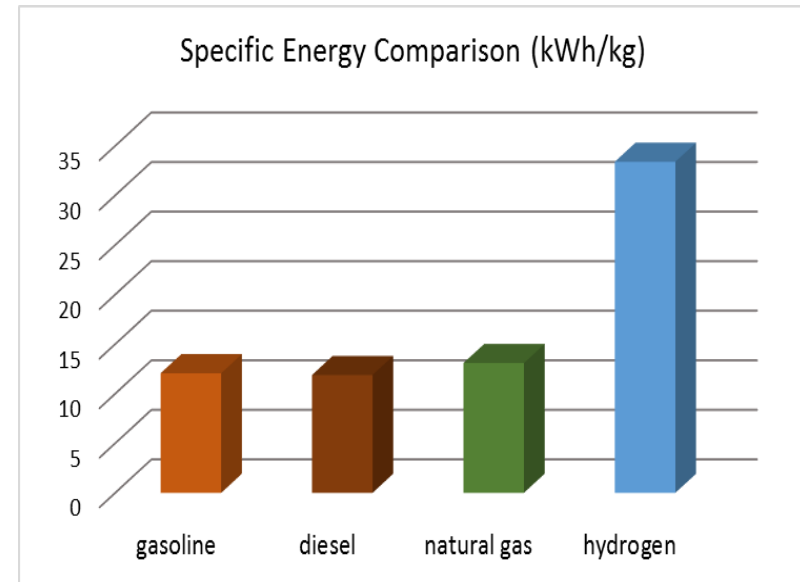
Hydrogen is Part of an All of the Above Portfolio

H₂ can be produced from diverse domestic sources

Many applications rely on or could benefit from H₂



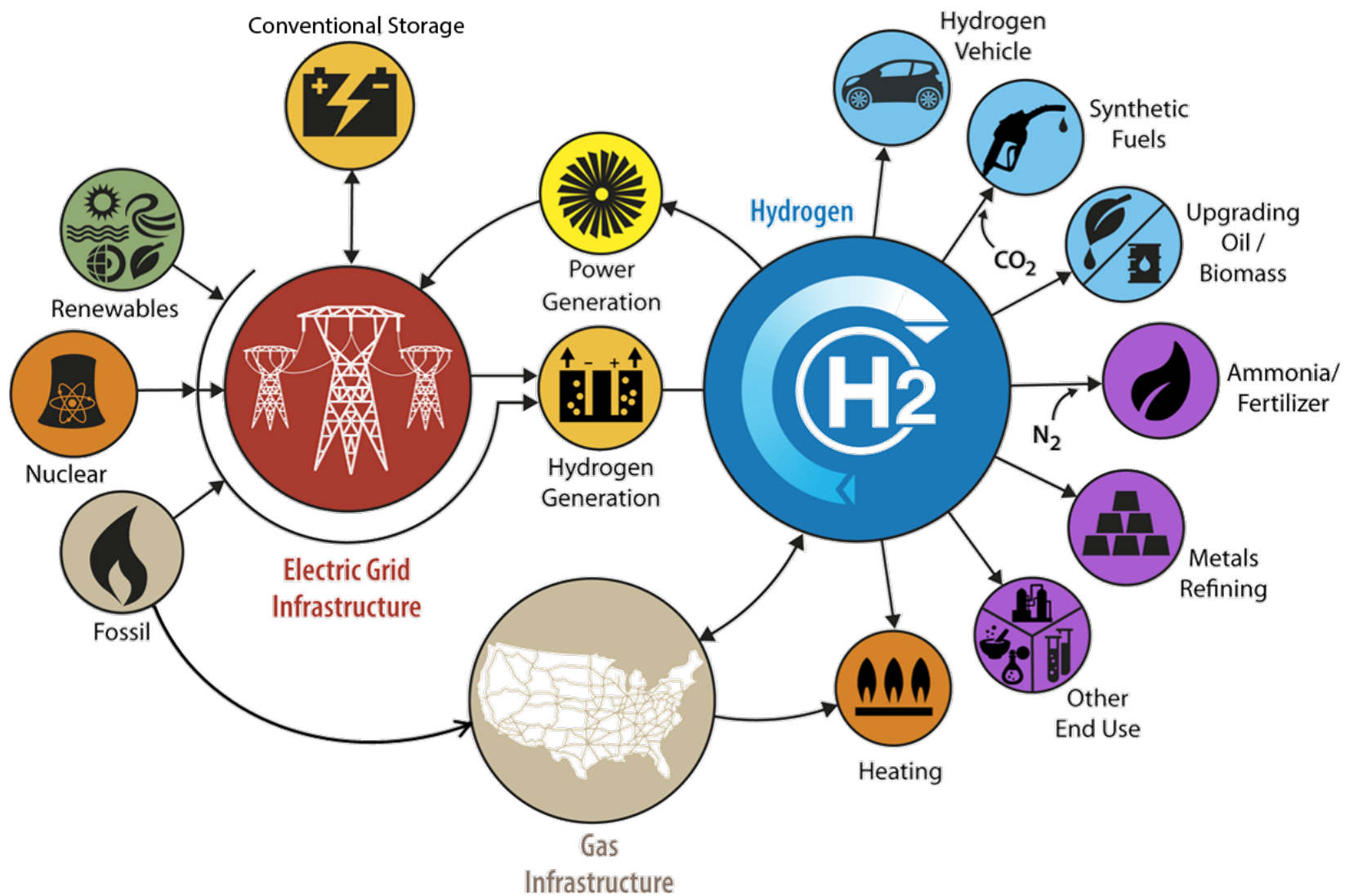
Very High Specific Energy



About *three times* more energy by mass than gasoline. But worse in terms of volume.

Clean, sustainable, versatile, and efficient energy carrier

H2@Scale: Enabling Affordable, Reliable, Clean, and Secure Energy across Sectors



More information at: www.energy.gov/eere/fuelcells/h2-scale

Life-Cycle Emissions- Today's Cars

Low, Medium & High Emissions/Mile for 2015 Technology



Fuel Cell Electric



Battery Electric



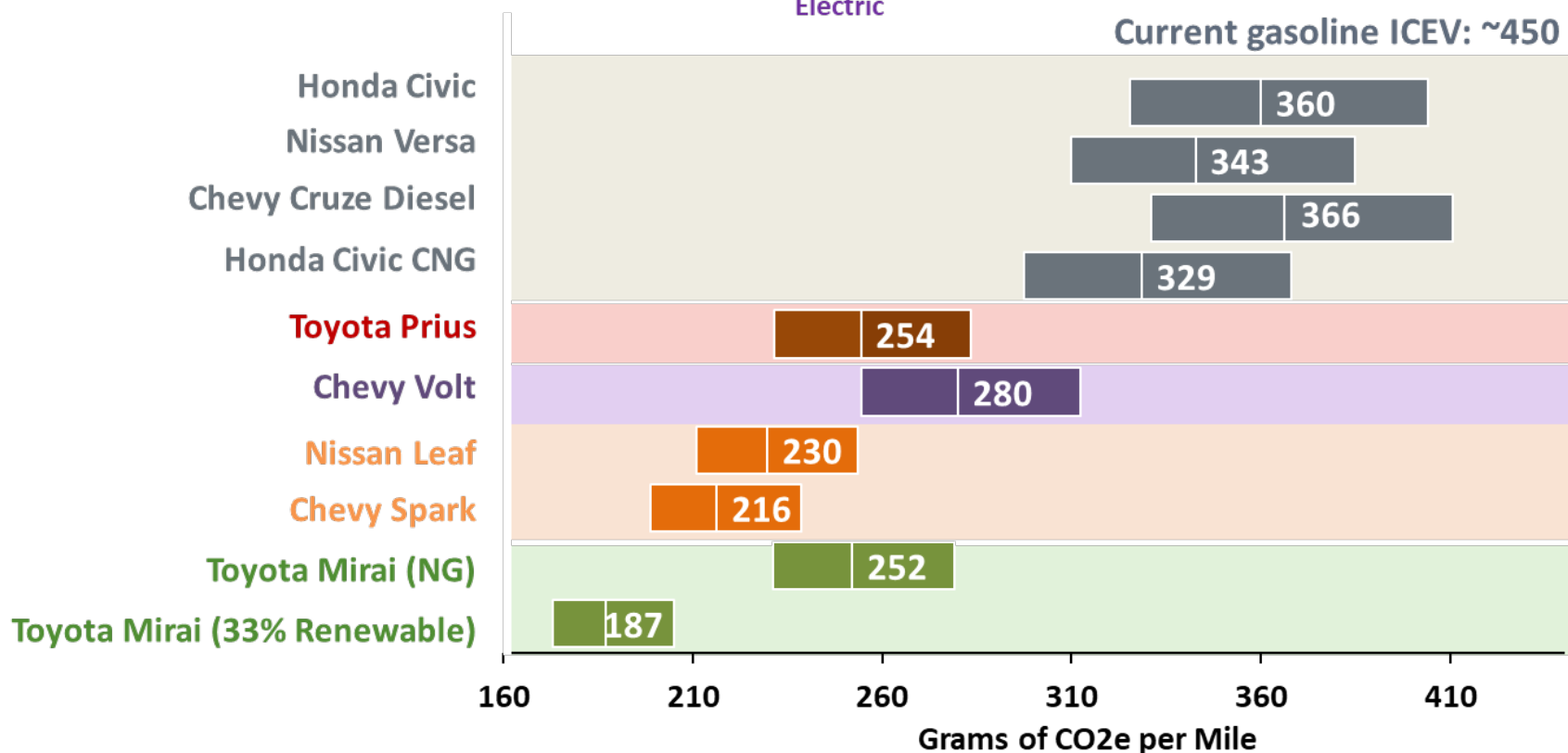
Extended-Range Electric



Hybrid Electric



Internal Combustion Engine



DOE cross office analysis example

Source: Program Record 16004

(https://www.hydrogen.energy.gov/pdfs/16004_life-cycle_ghg_oil_use_cars.pdf)

Life-Cycle Petroleum Use- Today's Cars

Low, Medium & High Petroleum Energy/Mile for 2015 Technology



Fuel Cell Electric



Battery Electric



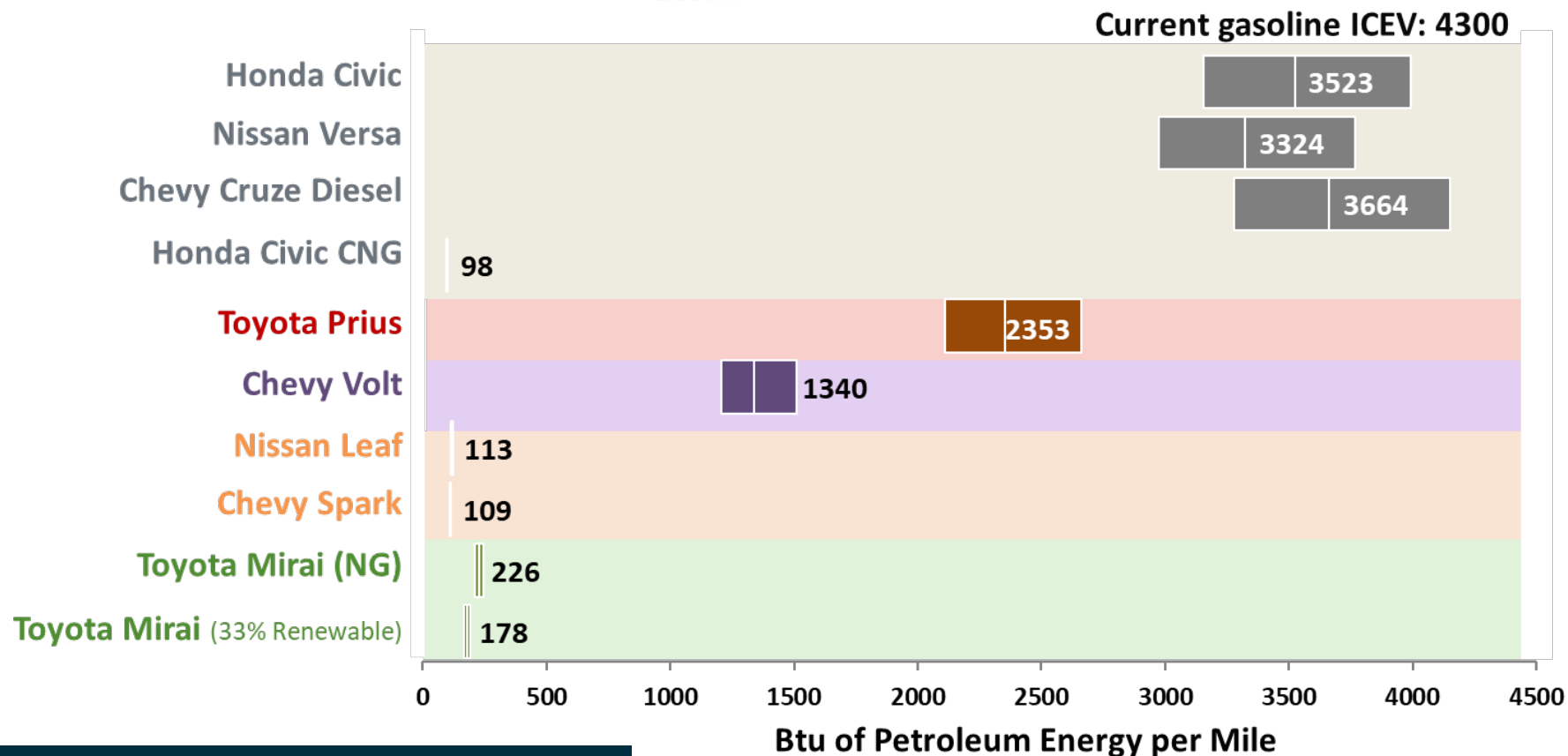
Extended-Range Electric



Hybrid Electric



Internal Combustion Engine

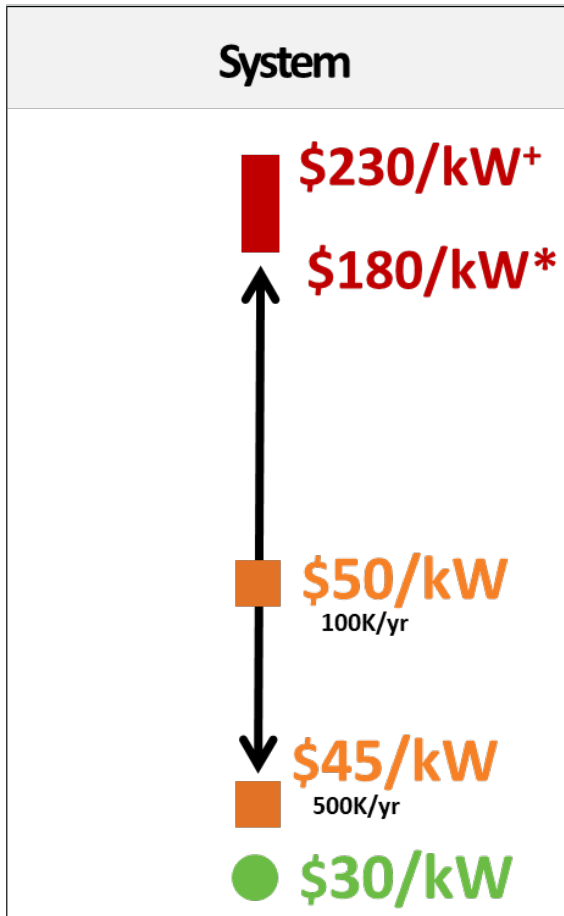


DOE cross office analysis example

Source: Program Record 16004 (https://www.hydrogen.energy.gov/pdfs/16004_life-cycle_ghg_oil_use_cars.pdf)

DOE Cost Status and Targets for R&D

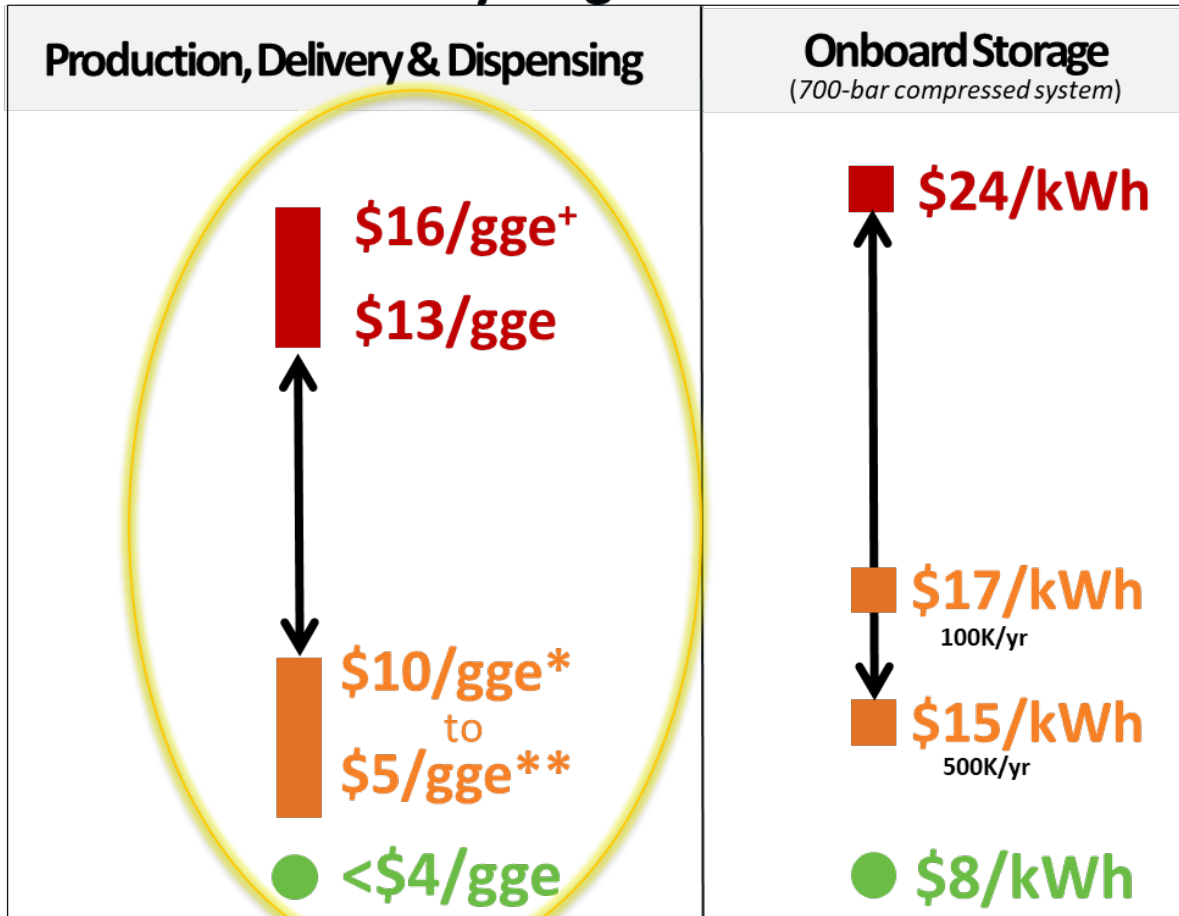
Fuel Cell R&D



*Based on commercially available FCEVs

**Based on state of the art technology

Hydrogen R&D



*Range assumes current production from NG and delivery and dispensing.

**Highest possible cost at high vol., assumes H₂ from electrolysis at \$5/gge and delivery via pipelines and liquid tankers at \$5/gge

**Lowest possible cost at high vol., assumes H₂ from SMR at \$2/gge and delivery via tube trailer at \$3/gge

● Ultimate Targets

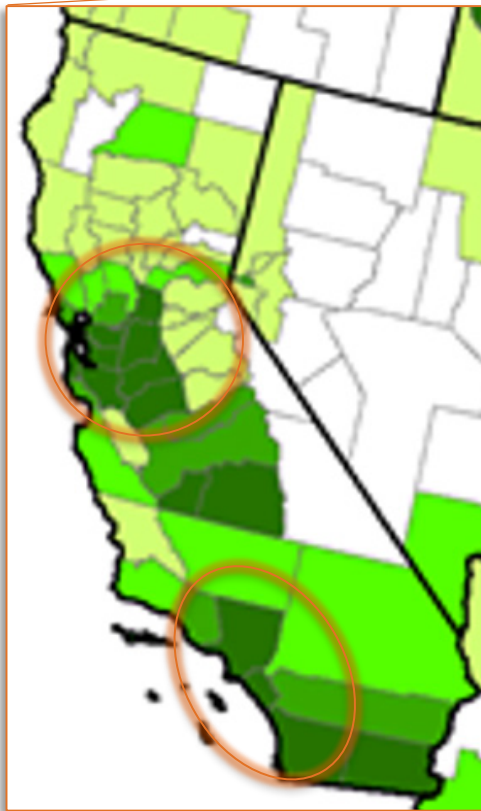
■ High-Volume Projection

■ Low-Volume Estimate

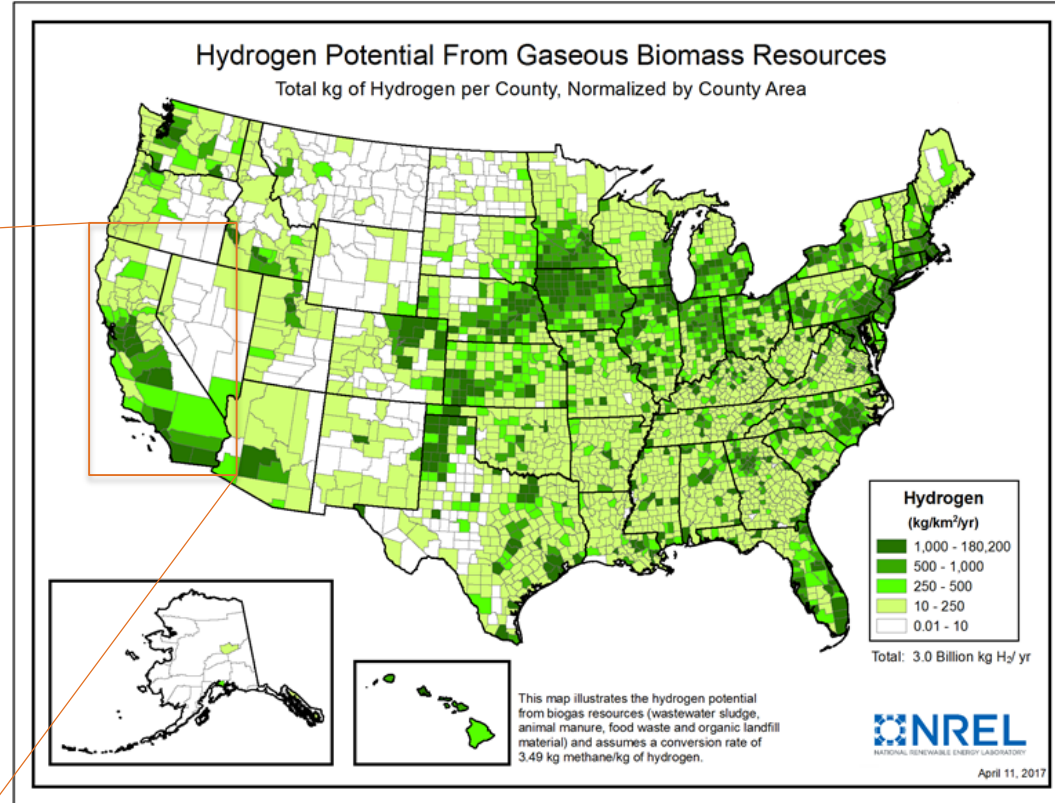
Notes: Graphs not drawn to scale and are for illustration purposes only. gge: gallon of gasoline equivalent

Biogas Resource for Renewable Hydrogen Production

Hydrogen from biogas
already available in some
California fueling stations



Currently **39 stations** operating in CA
Additional 25 funded

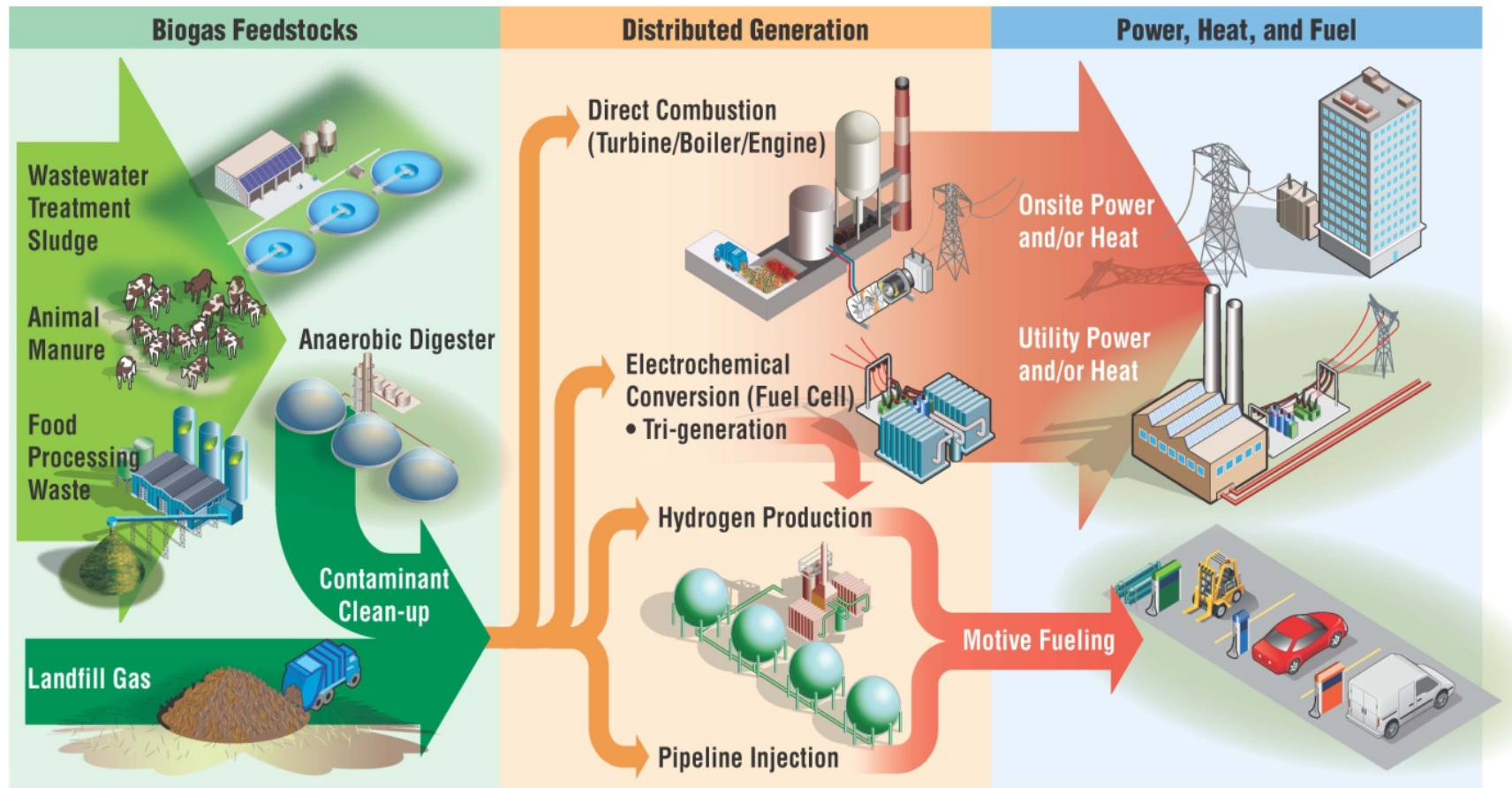


Technical Potential:

- 3 B kg H₂/year from combined biogas sources
- **600 M kg H₂/year from landfill gas**

Landfill gas has the potential to provide enough hydrogen to support 2-3M FCEVs/year

The Biogas-to-Energy Process



The “New” Business Case: Using biogas to provide both electric power and/or heat and transportation fuel

BMW Landfill Gas Purification Project Completed

Validated technical parameters and **demonstrated a potential business case** for on-site cleanup and reformation of **landfill biogas into hydrogen** at a scale to support full scale operation for fueling MHE.



BMW South Carolina assembly plant: world's largest fuel cell deployment at one site.



“First ever” fueling of fuel cell product (MHE) of hydrogen reformed from landfill gas. Testing showed no difference in stack performance vs. delivered H₂ source.



Pilot-scale H₂ testing skid at BMW assembly plant.

Landfill gas to H₂ fuel was used for lift trucks at BMW plant



Over 300 MHEs -- largest fuel cell MHE fleet

23,000 deployed nation-wide
~13 million H₂ fuelings



On-site, renewably-generated hydrogen production capability

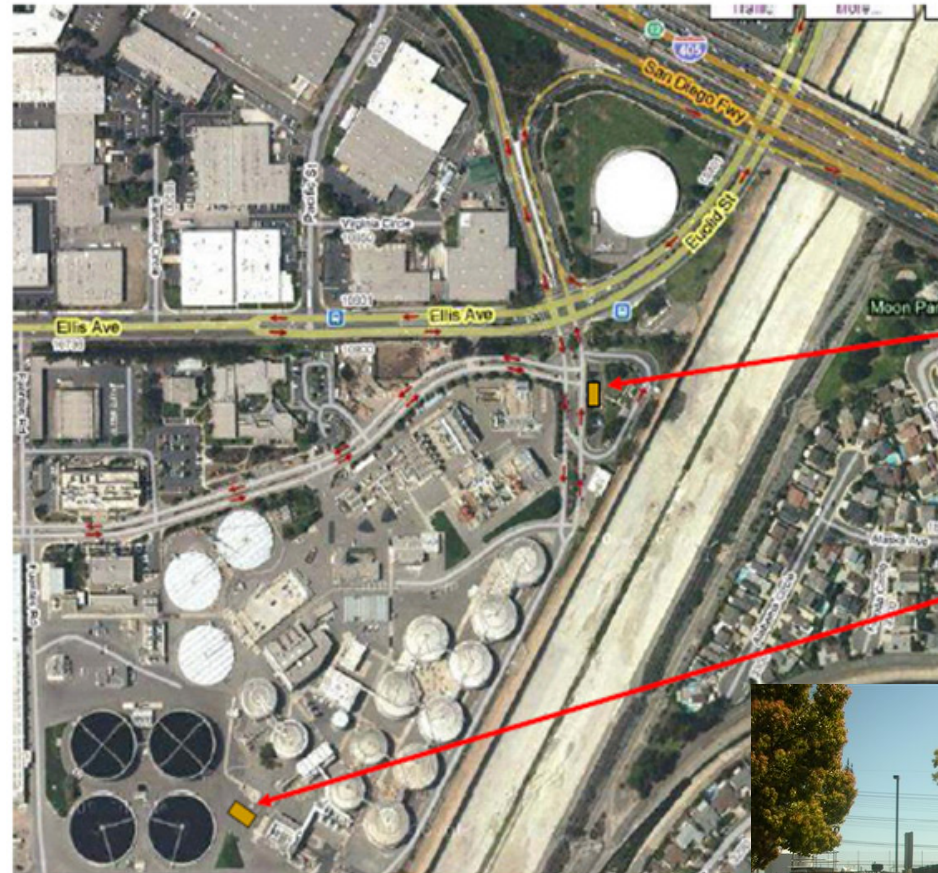
Small steam reformer converted landfill methane to H₂

Wastewater Biogas-to-Hydrogen Project Completed: Orange County Sanitation District, California

World's first tri-generation fuel cell and hydrogen energy station to provide transportation fuel to the public and electric power to an industrial facility.

Molten carbonate fuel cell

- High efficiency
- Co-production of hydrogen
- Anaerobically digested biogas as fuel



Orange County Sanitation District (OCSD) - site

Renewable H₂ Filling Station

ADG fueled DFC-H₂ Production Unit

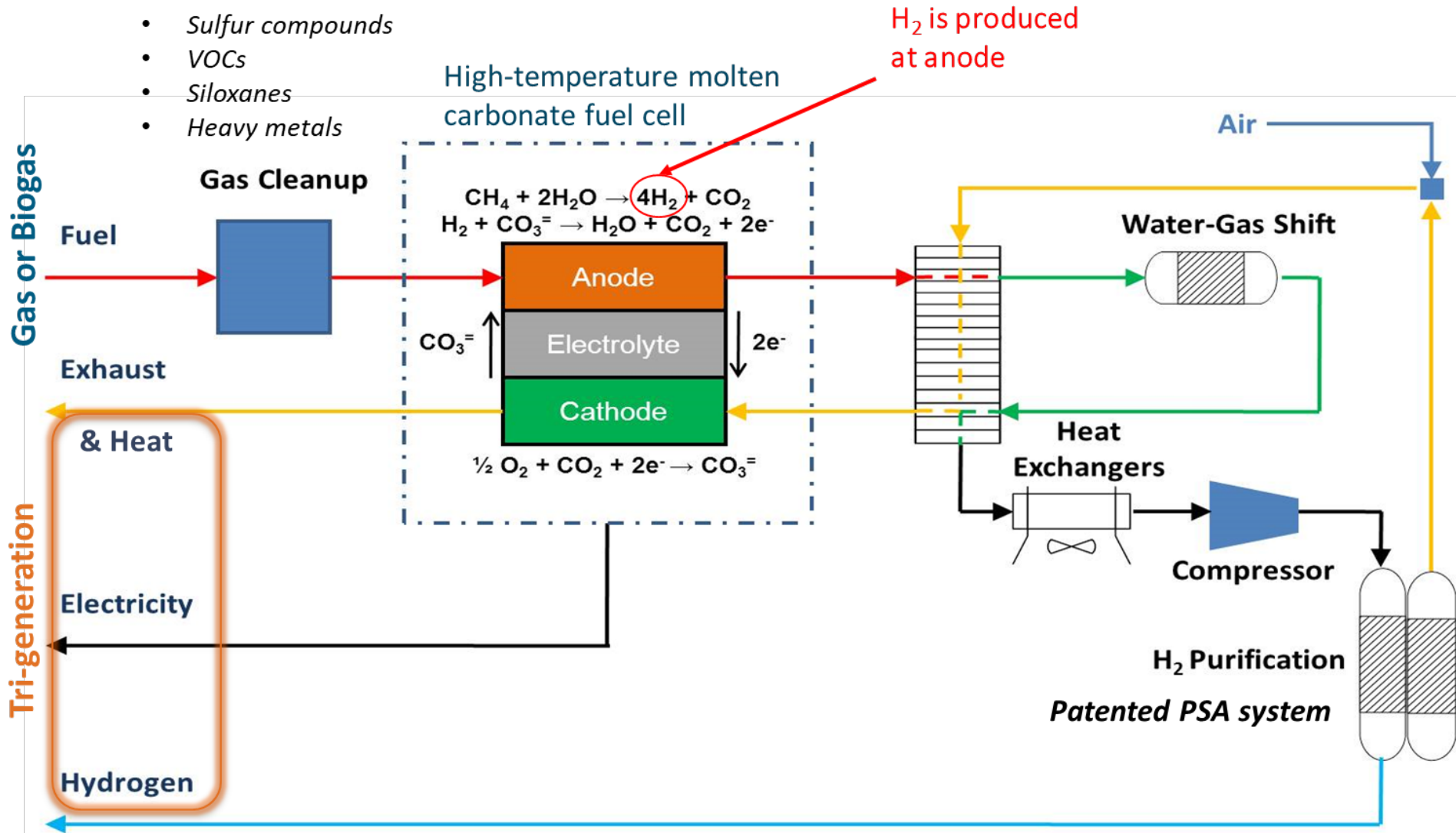
Partners: Air Products, FuelCell Energy, CARB, SCAQMD and DOE



Tri-Generation Process

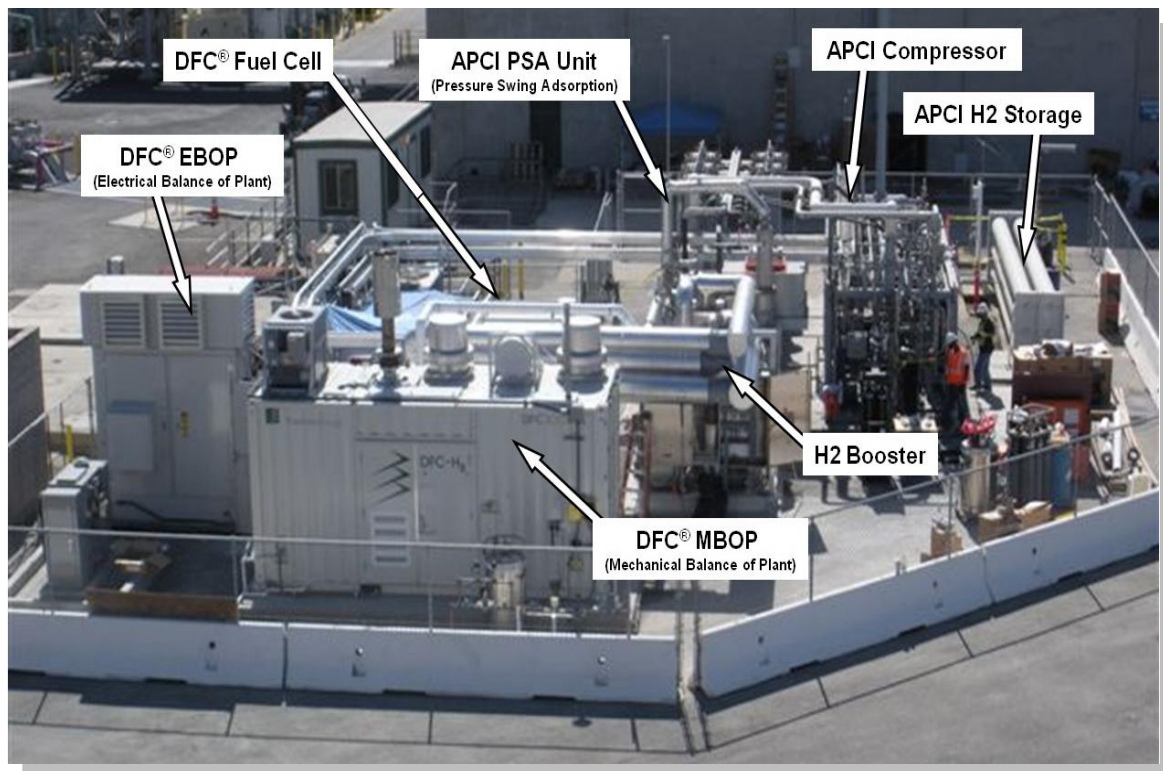
Quadrogen system removes:

- Sulfur compounds
- VOCs
- Siloxanes
- Heavy metals



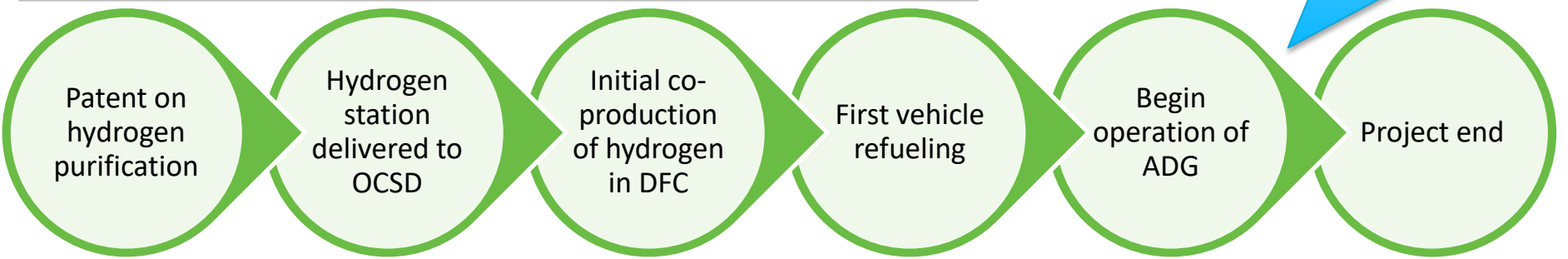
Validation of an Integrated Energy Station

System produces hydrogen and electricity from wastewater gas—mitigating treatment plant emissions while producing high-grade, high-value energy products.



- Fueled with Orange County municipal wastewater gas
- Produced 100 kg/day H₂ (350 and 700 bar)
- Generated approximately 250 kW/day electricity
- 54% efficiency coproducing H₂ and electricity

Used/mitigated >5M scf ADG
Produced > 5,700 kg H₂
Exported > 1GWh electricity



FuelCell Energy Tri-Generation Project Announcements

Port of Long Beach

Plans to build MW-scale carbonate fuel cell power generation plant and hydrogen fueling station at the Port of Long Beach.

- Expected operation in 2020
- Fueled by agricultural waste
- 1.2 tonnes/day hydrogen
- 2.35 MW/day electricity

The facility will supply all Toyota fuel cell vehicles moving through the Port, including light-duty and heavy-duty vehicles.

Partners: Toyota and Air Liquide

Coyote Canyon Landfill

FuelCell Energy won exclusive rights to develop landfill gas as a source of renewable fuel

- Located in Newport Beach, CA – close to largest FCEV market (LA)
- Expected operation in 2020
- 1.2 - 2.4 tonnes/day hydrogen



Additional news:
FuelCell Energy awarded ~\$3.8 M from SCAQMD for another renewable fuel cell project

Introducing the Center for Hydrogen Safety

Leverages new partnership to promote collaboration on H₂ safety



CENTER FOR
Hydrogen
SAFETY



HYDROGEN
Safety Panel



HYDROGEN
Emergency Response
Training Resources

<https://www.aiche.org/CHS>

U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

LAUNCH EVENT

APRIL 2

2019 AIChE Spring Meeting, New Orleans
15th Global Congress on Process Safety

Save the Date

2019 Annual Merit Review

April 29 - May 1, 2019

Crystal City, VA

Early Bird Registration Ends March 3

www.hydrogen.energy.gov

Thank You

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<https://www.energy.gov/eere/fuelcells/h2scale>