Howell Power to Gas Project

NGA Spring Conference
April 20, 2022

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New Jersey Resources

Why is NJNG investing in Hydrogen and RNG?

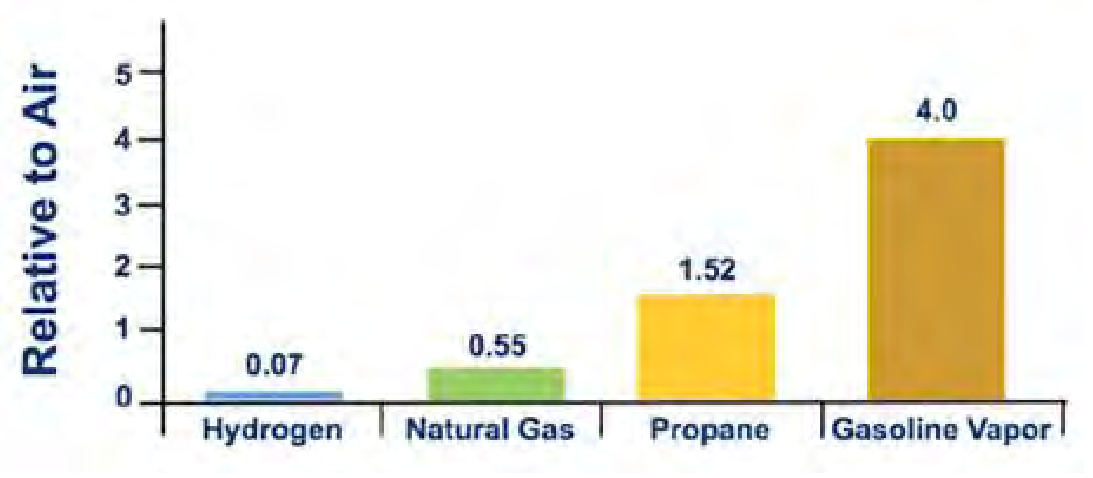
- NJ Energy Master Plan (EMP) set an ambitious goal of 100% clean energy by 2050
- NJR recently set a goal to achieve Net-Zero carbon emissions from our New Jersey operations by 2050.
  - Scope 1 and 2 GHG Emissions
- Green Hydrogen and RNG are opportunities to support the EMP goals while continuing to serve our customers
  - Natural Gas emits 27% less CO2 than compared to diesel but still has emissions
- Ability to reuse/repurpose existing assets in the ground.
  - NJR focuses on maintaining a best-in-class distribution system, and we have modernized it to be one of the best in the country. These upgrades are important when transporting alternative fuels like hydrogen.
  - Over the years NJNG has remained focused on infrastructure upgrades to ensure that our distribution network is one of the most environmentally sound in the nation when it comes to fugitive emissions
- Electrification will be expensive
  - California's "Duck Curve" causes renewable curtailment and rolling blackouts
  - Extremely old and aging electrical grid
  - Heat load in cold climates are massive
  - Cost of electric heat pump to replace natural gas furnaces is high
  - Electrification means a single source of energy
- When hurricane/storms hit, people remember the need for redundancy in energy

Hydrogen Facts

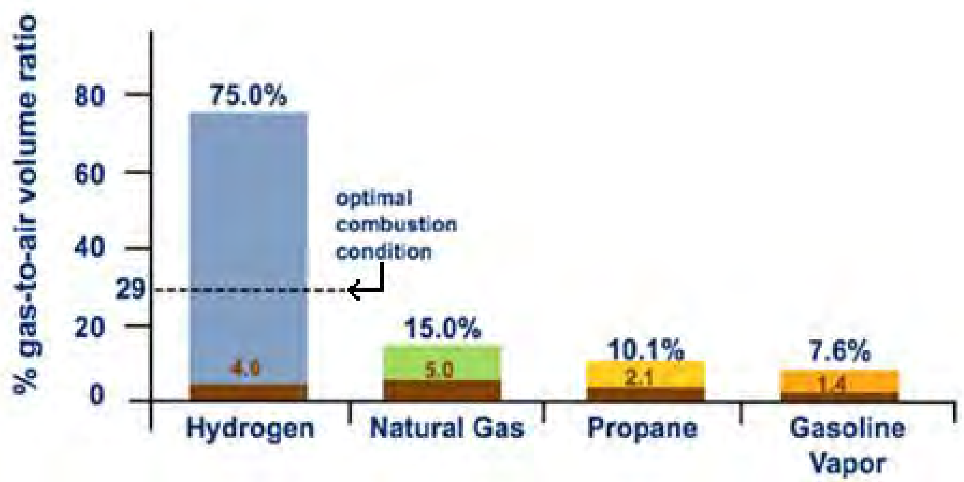
- Most abundant chemical substance in the universe
- Colorless, Odorless & Tasteless
- Non-Toxic
- Broad Flammability Range (4%-75%)
- Hydrogen rises at almost 45mph (20m/s) [1]
  - Hydrogen rises 6x faster than natural gas
- When Hydrogen is burned, it recombines with Oxygen and emits water vapor.
- Zero Greenhouse Gases, Air Pollutants or hazardous air emissions

[1] U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, Hydrogen Safety Fact Sheet Series

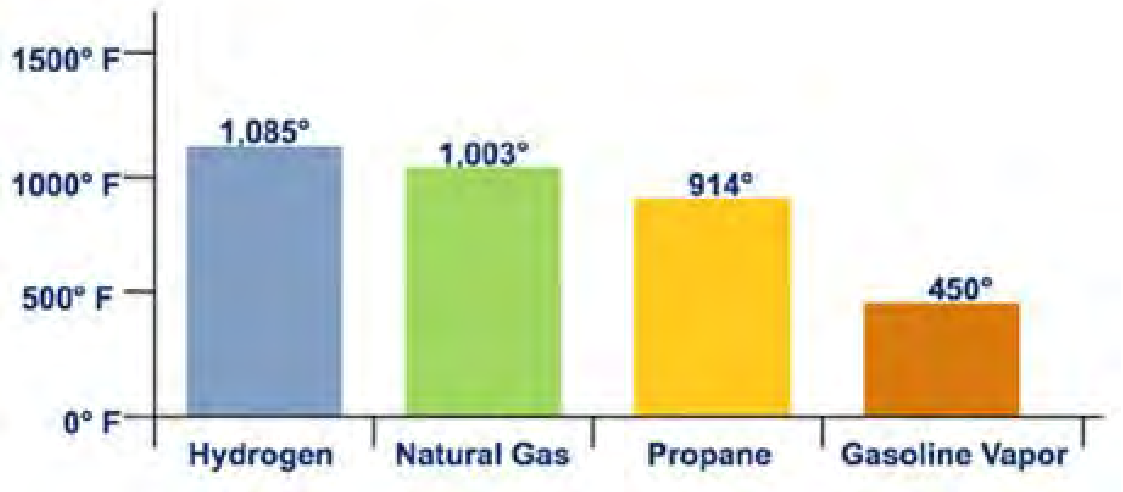
Hydrogen Characteristics Comparison



Relative Vapor Density to Air



Flammability Range



Auto Ignition Temperature

Propane and Hydrogen Flame at Night

https://h2tools.org/hydrogen-compared-other-fuels

Hydrogen VS Natural Gas Comparison

Natural Gas

- Heating Value: 24,000 BTU/lb
- Relative Density to Air: 0.55
- **1,000 scf NG = 1 MMBTU**

Hydrogen

- Heating Value: 61,000 BTU/lb
- Relative Density to Air: 0.07
- **1,000 scf H2 = 0.32 MMBTU**

- Hydrogen requires about 3 times the volume of Natural gas to achieve the same energy content.
- Studies indicate 5-20% blend is generally safe for system integrity, safety and existing end user equipment. [1]
- Little to no additional risk when blended in low concentrations
- No modifications required to system or end users at low blend percentages
- At higher pressures, Hydrogen causes embrittlement in steel piping
  - NJNG is an industry partner on the Pipeline Blending CRADA – A HyBlend Project
    - Includes the DOE, 4 National Laboratories and many Industry partners

[1] NREL, Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues. https://www.nrel.gov/docs/fy13osti/51995.pdf

3 Main Types of Hydrogen Production

- Green: Hydrogen created via purely renewable energy sources
- Blue: Hydrogen reformed from Natural Gas with Carbon Capture and Storage (CCS)
- Gray: Hydrogen reformed from Natural Gas without CCS

Hydrogen Uses

- Petroleum Processing: 68%
- Fertilizer Production: 21%
- Other (Fuel Cells, Oxygen, Rocket fuel, metallurgy, textiles, etc): 11%

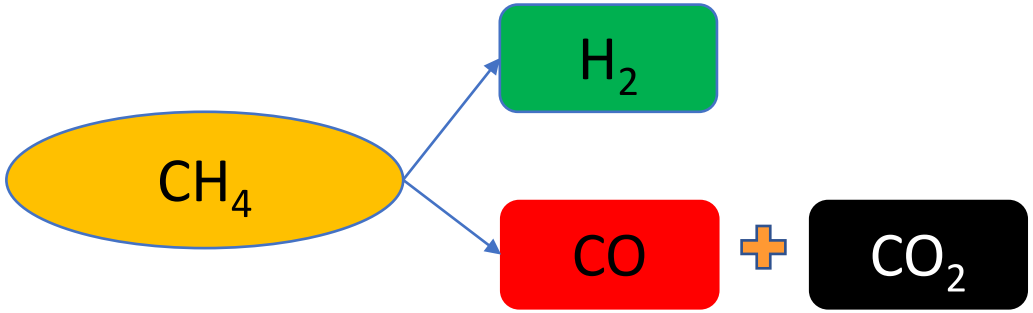
- Hydrogen has been safely used in Ammonia production since the late 1920's

- Electrolyzers have been used in Submarines and Space Stations for Oxygen Generation since the late 1950's

- Approximately 1,600 miles of Hydrogen pipelines operating in the US [1]

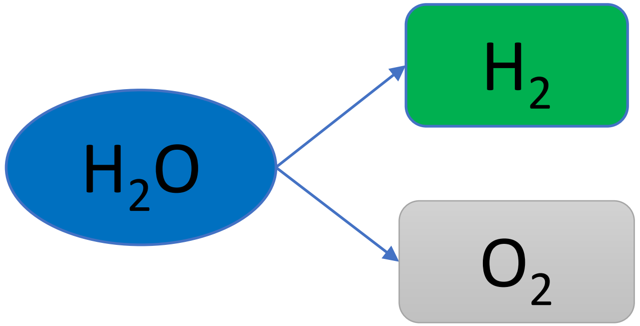
Glomfjord, Norway; 1953 – 1991
Nel Hydrogen (Norsk Hydro)

[1] U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, Hydrogen and Fuel Cell Technologies Office

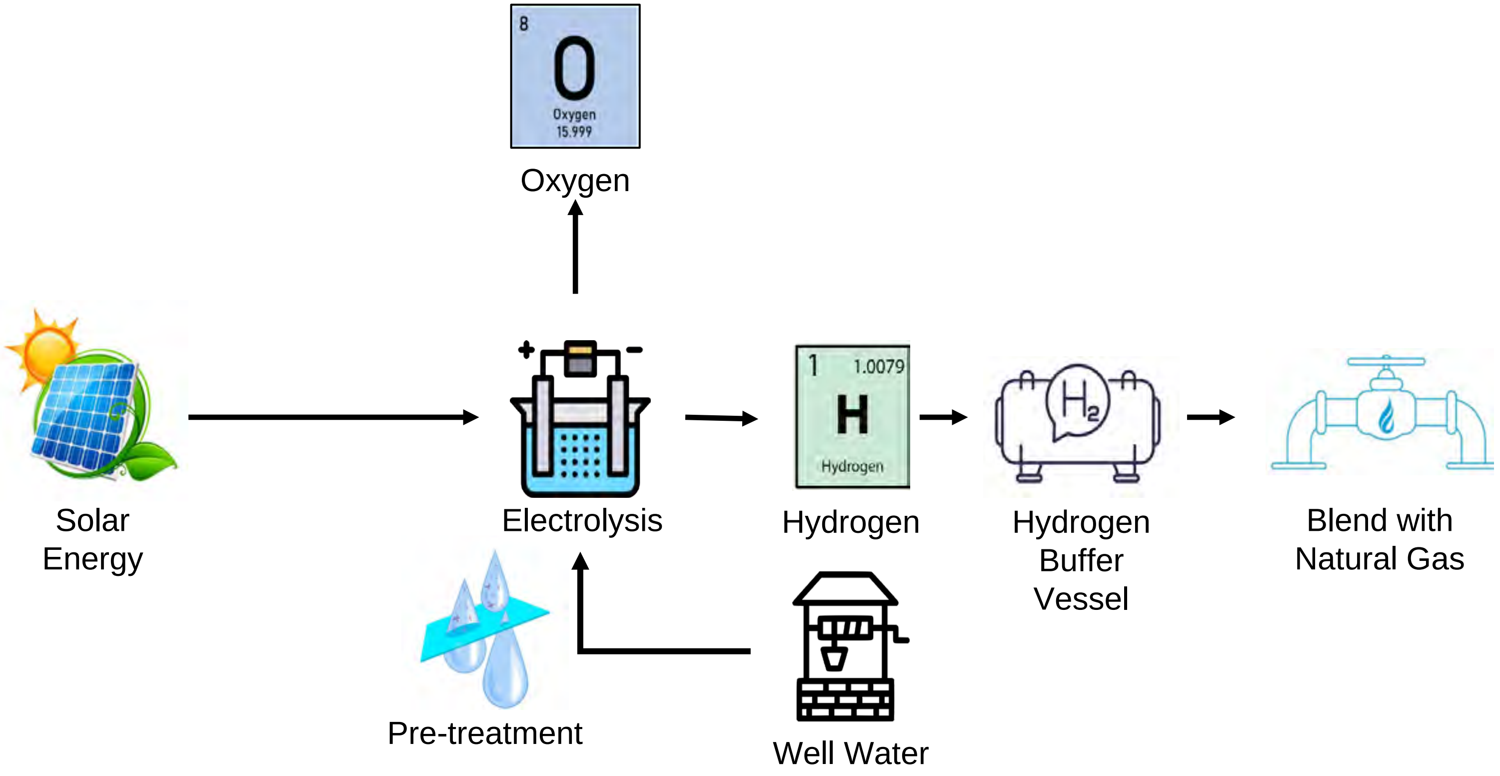


- Steam Methane Reforming
  - Extracts hydrogen from methane
  - Combines high-temperature (1,300-2,000°F) steam with natural gas
  - Efficiencies between 60-75%
  - Carbon intensive

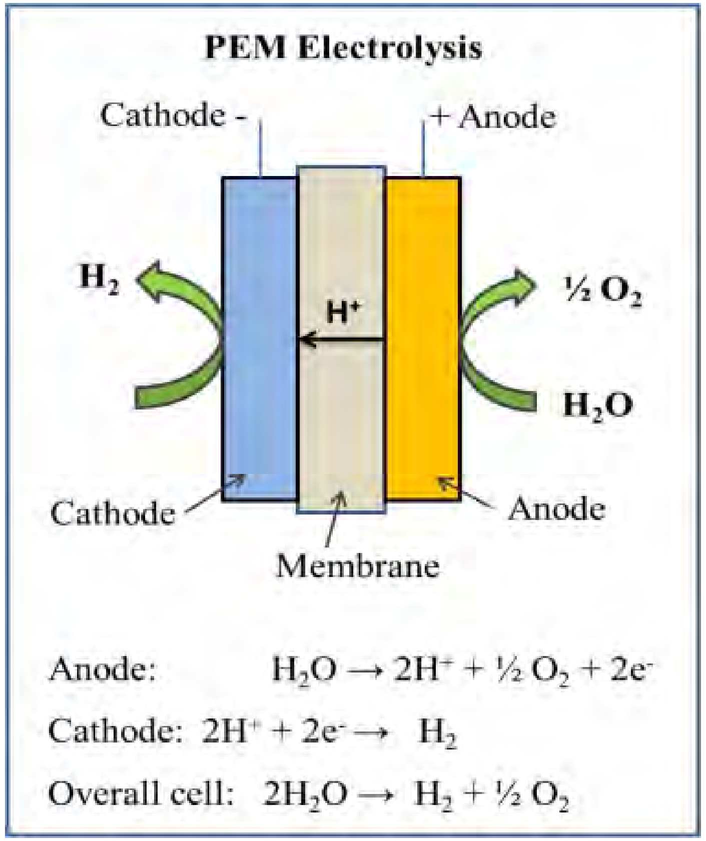
- Electrolysis
  - Electricity applied to water separates hydrogen and oxygen atoms
  - Efficiencies of 70-80% with a 2030 goal of 82%-86%



NJNG Power to Gas Concept



Proton Exchange Membrane



Kumar & Himabindu (2019). Hydrogen production by PEM water electrolysis. ScienceDirect

Key Facility Elements

1. Transformer
2. 35kW Generator
3. E&I Enclosure, Water Pretreatment
4. Supply Well
5. Glycol Chiller
6. Containerized C Series Nel Electrolyzer
7. Underground Lift Station
8. H2 Buffer Vessel
9. Planned Solar Array Location
10. Injection Point
11. Flow Meter

Howell PTG Hydrogen Production and Carbon Offset

Maximum Green Hydrogen production

- 30Nm3/hr = 1,140 SCFH
- 65 kg per day
- 8.7 MMBTU per day

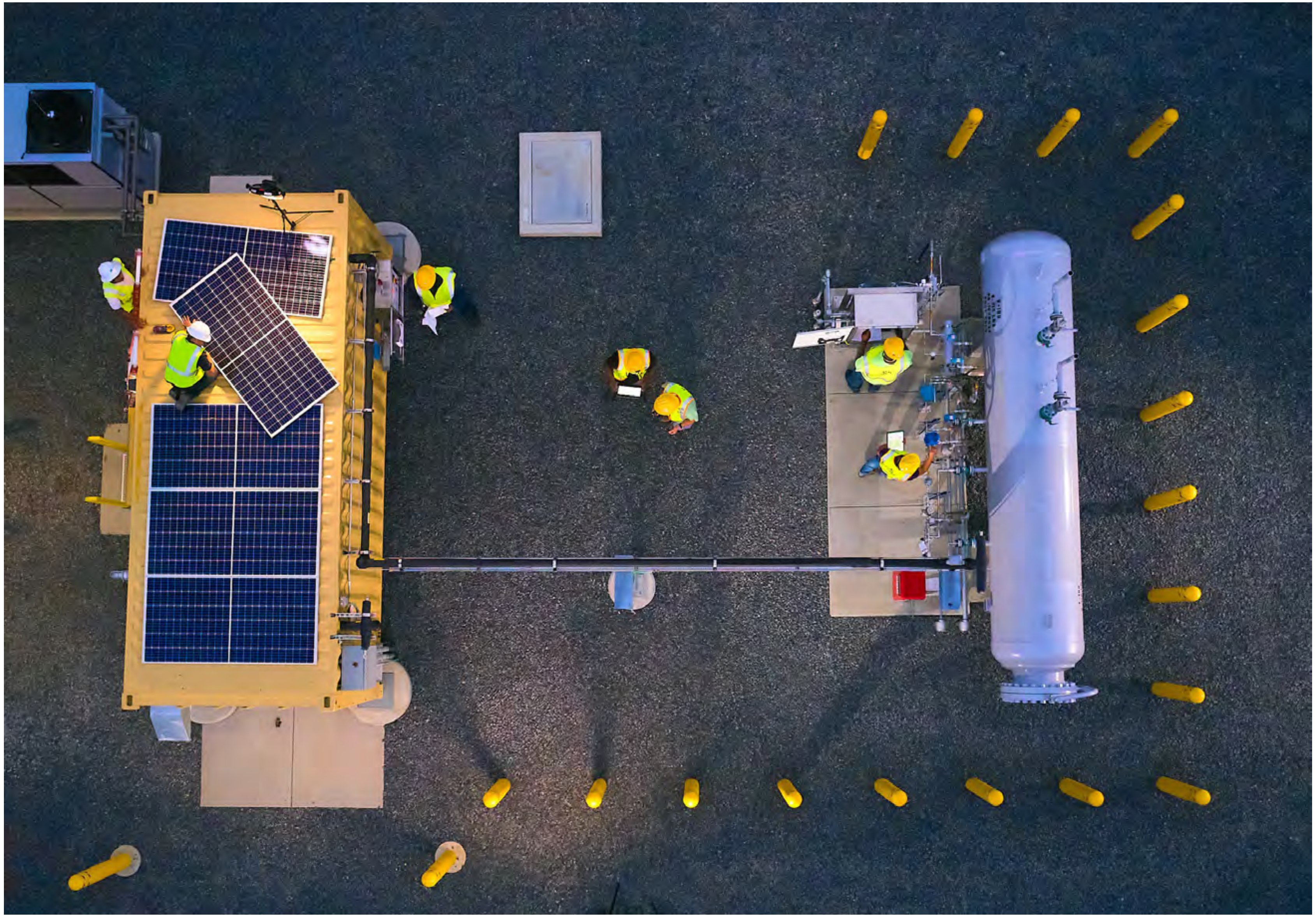
Hydrogen offsets up to 180 US Tons of CO_2 per year

- 400,000 miles driven by a passenger car
  - Equivalent to removing 27 cars off the roads each year
- 18,000 gallons of gasoline
- 180,000 pounds of coal burned

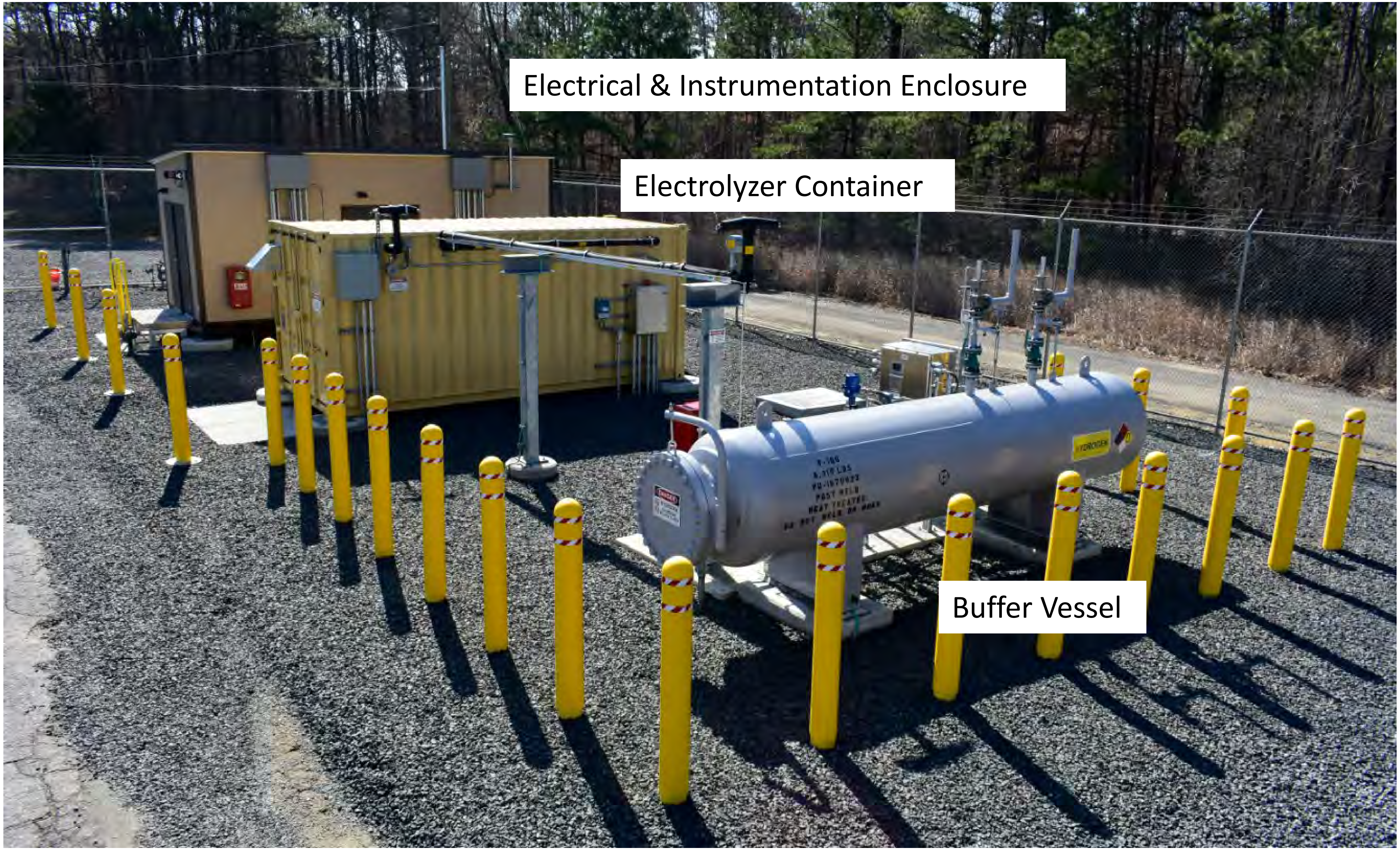
Maximum Oxygen production

- 15 Nm3/hr = 47 lbs/hr = 1,128 lbs/day
- 400,000 lbs of oxygen per year

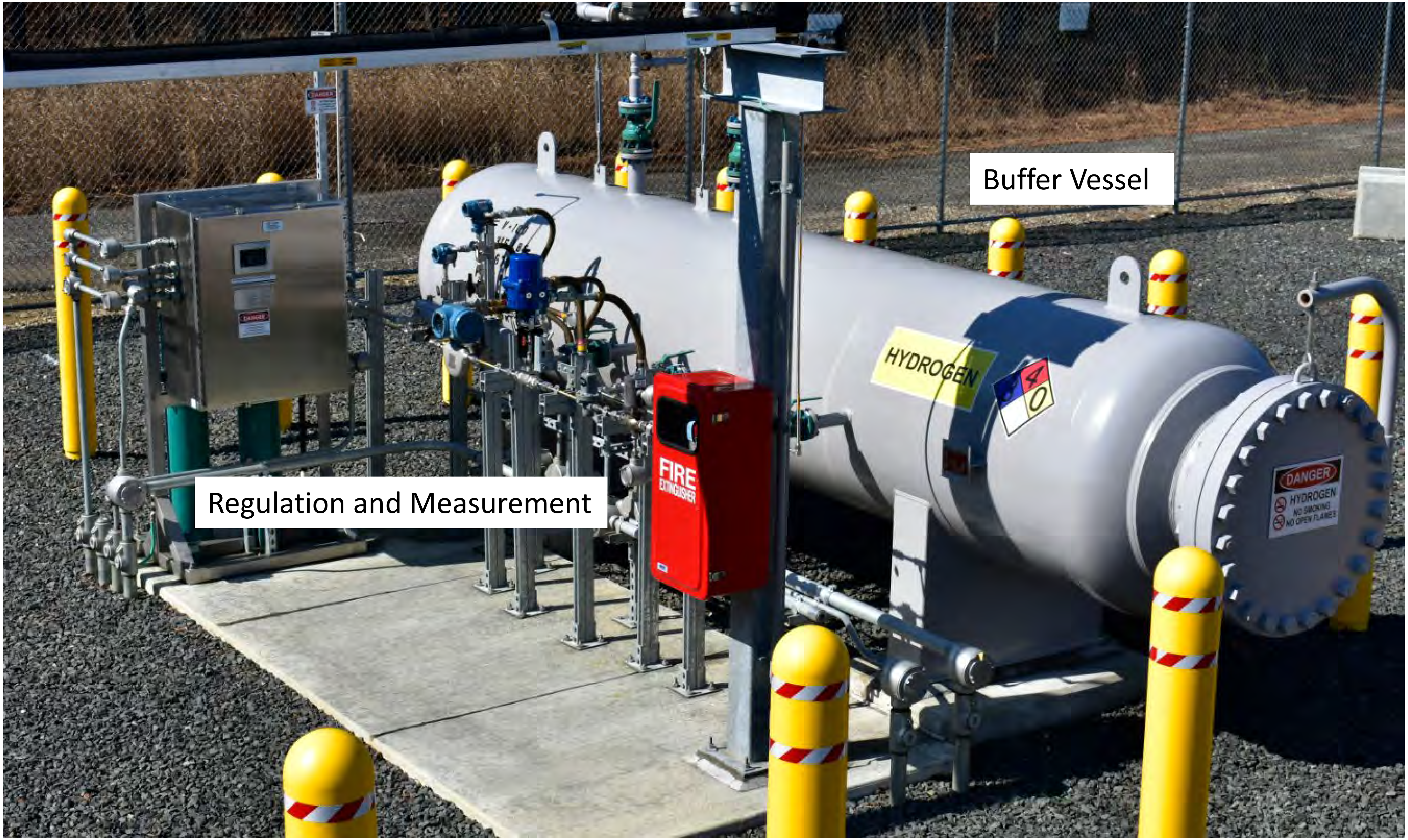
Part of NJNG's Sustainability Goals and Support for New Jersey Climate Goals



Overall Plant

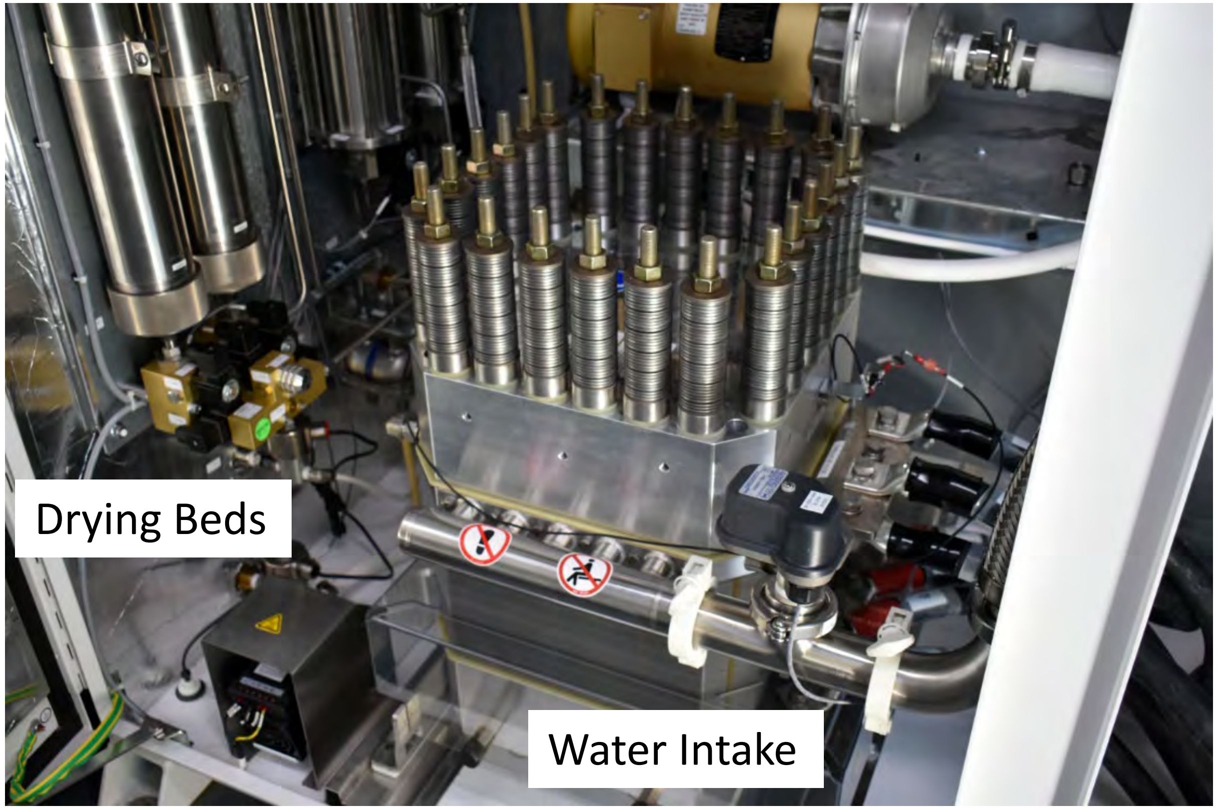


Hydrogen Buffer Vessel



Electrolyzer Stack

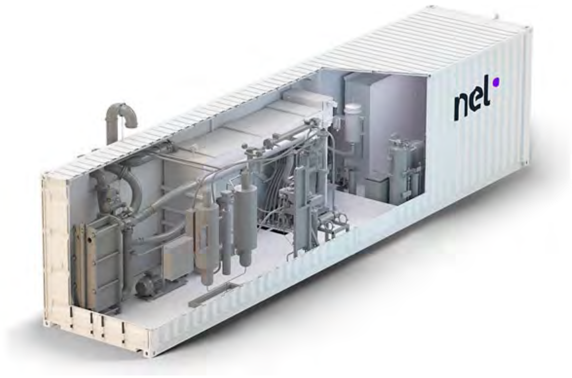
Electrolyzer Stack Installation



Hydrogen Sendout Piping

Howell PTG Operational Considerations

- Vents pure Oxygen as a byproduct
- Dryer beds vent hydrogen when saturated
- Area Classification of Hydrogen is Class 1, Division 1&2, Group B
- Consumes 7.1 gallons of deionized water per hour
  - Water Treatment and Discharge considerations
- Reject water potentially needs to be treated before discharging to ground water
- Noise due to chiller fans
- Additional heating considerations required in cold climates
  - Keep required air changes in mind within electrolyzer



Nel Hydrogen
*Containerized M Series

Lessons Learned

- Water usage and discharge efficiency
  - More efficient solutions can be designed
  - Freshwater resources at scaled facilities may be harder to obtain
  - City water and city sewer is preferred

- Hydrogen pipeline (B31.12) vs natural gas pipeline (B31.8)
  - Alternative is to bring natural gas pipeline to H2 interconnection
  - Additional welding, testing and inspection requirements

- Consistent natural gas flow is preferred
  - Consistent demand avoids interruptions in hydrogen production

- Injection point today may affect future blend rates
  - In the future, upstream injection may cause overlapping blending areas

- Safety system has ability to trip Electrolyzer Container HVAC
  - Water based process is susceptible to freezing

Future Projects

- Scaled (10-30MW) blending projects
  - Co-locating at Regulator Stations
  - Focused on 125 and 250psi distribution networks

- Hydrogen Fueling Stations
  - NJNG Fleet Vehicles
    - Passenger Vehicles
    - Medium Duty Trucks
  - Public stations for Fleets

- Methanation of Captured Carbon
  - $CO_2 + 4H_2 <-> CH_4 + 2H_2O$
  - CO_2 is a RNG gas upgrading byproduct typically sent to thermal oxidizer
    - Raw Biogas typically consists of ~40% CO_2 and ~45% CH_4
    - Methanation can nearly double the amount of methane generated
    - Requires a scaled Electrolyzer

Siting Considerations

- Overlapping injection locations
- Percentage blend of H2 generation compared to lowest natural gas flow
- City water/sewer vs well water and discharge
- Availability of land for onsite solar
  - Lowers cost of electricity
- Distance to nearest electrical substation
  - Depending on scale, 34.5kV, may not be enough power. Dedicated express feeders likely required
  - Larger scaled projects may require transmission voltage, 69kV+.
- Co-location of Blending and Fueling Station (mini-hydrogen hub)
  - Multiple uses of hydrogen at a single location for scale
- Balance of Plant sizing for future electrolyzer expansions