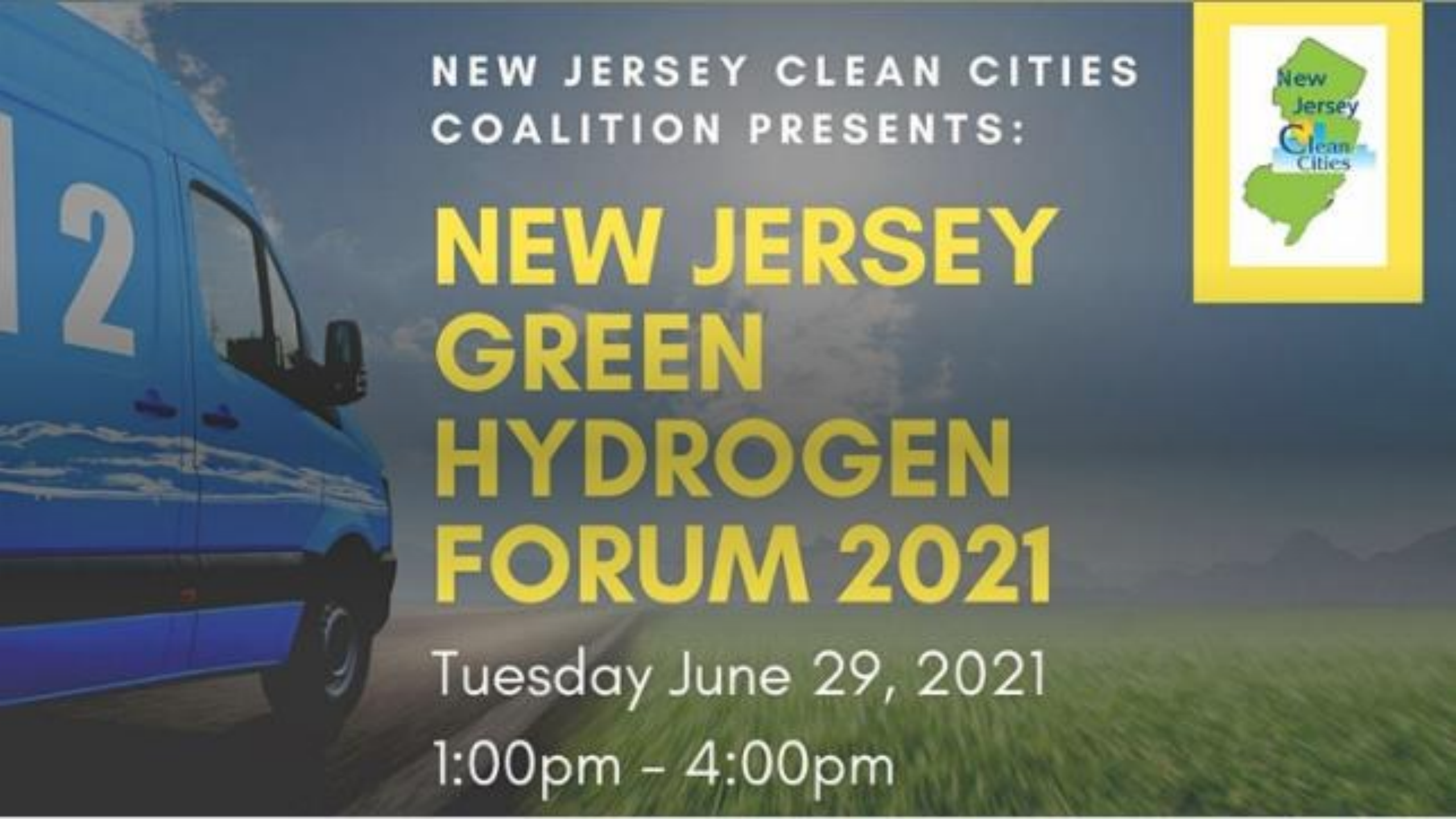

NEW JERSEY CLEAN CITIES COALITION PRESENTS:
NEW JERSEY GREEN HYDROGEN FORUM 2021
Tuesday June 29, 2021
1:00pm - 4:00pm
New Jersey Clean Cities

The Economic, Environmental and Energy Potential of Green Hydrogen

Production, Distribution and Use in New Jersey

Chuck Feinberg
Executive Vice President, Greener by Design
Executive Director, NJ Clean Cities Coalition
June 29, 2021

The New Jersey Clean Cities Coalition is an IRS 501(c)3 non-profit corporation and is formally designated by the US Dept. of Energy as a Clean Cities Coalition.

We are the only state-wide entity dedicated to the establishment of Public/Private Partnerships for the advancement of clean alternative fuels and development of equitable, resilient and energy-efficient mobility systems.

Framing today's forum

This forum is intended as the start of a years-long conversation – we hope to facilitate stakeholder interaction, project development, and regulatory/policy and user awareness.

The Energy Future

- **We must increasingly depend upon solar and wind power**
  - Air quality, Greenhouse gas emissions & climate
  - Energy, environment, & geopolitical sustainability
  - Environmental Justice
- **The dynamics of such a future are challenging and will require complementary dispatch and massive storage capabilities**
  - Batteries, hydrogen energy storage
- **HYDROGEN will become the indispensable zero emissions fuel and energy storage medium to enable this future**
  - Long duration energy storage
  - Massive energy storage amount
  - Hydrogen & its derivative fuels
  - Will be lower cost (separate power/energy scaling)
  - High round-trip efficiency possible
  - Reliability & resilience (underground infrastructure)

Why Hydrogen? Industry

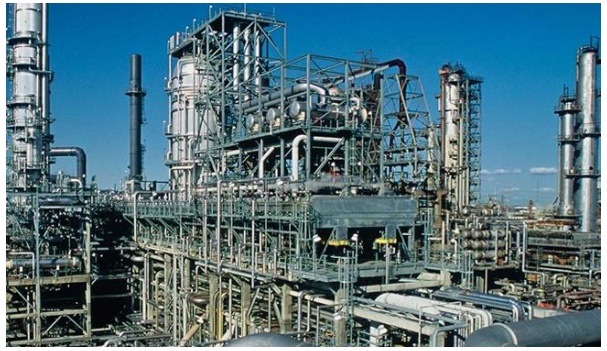
Many examples of applications that cannot easily be electrified or decarbonized

Steel Manufacturing & Processing

Cement Production

(Photo: ABB Cement)

Plastics

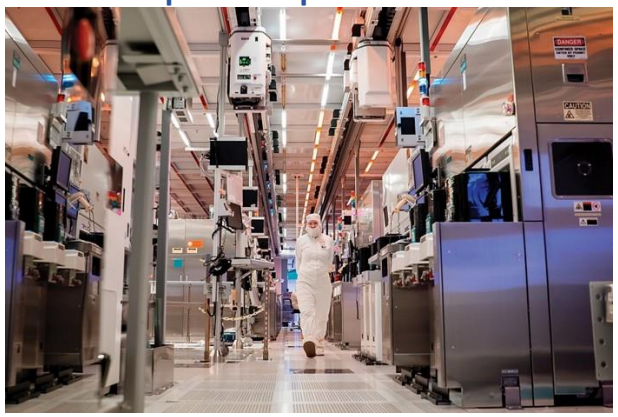


(Photo: DowDuPont Inc.*)*

Ammonia & Fertilizer Production

(Photo: Galveston County Economic Development)

Computer Chip Fabrication

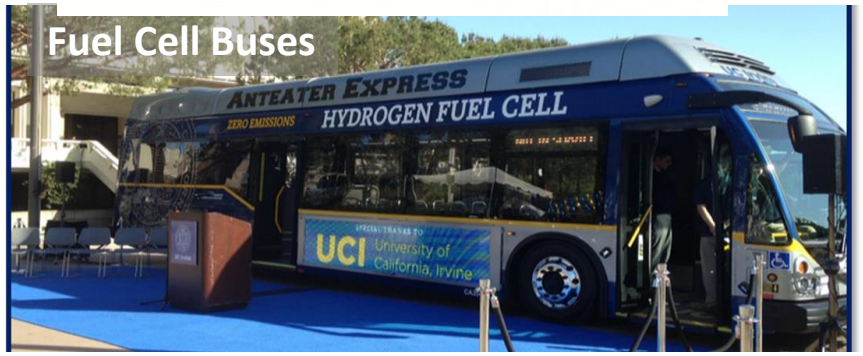


(Photo: American Chemical Society)

Pharmaceuticals

Why Hydrogen? Transport

Provide zero emissions fuel to difficult end-uses



Anything that requires (1) rapid fueling, (2) long range, (3) large payload

Key Benefits of Hydrogen

- Can be produced from diverse domestic resources for use in multiple sectors, or for export.
- Highest energy content by weight of all known fuels—1kg of H2 has about the same energy content as 1 gallon of gasoline which weighs 2.8 kg.
- Can enable zero or near-zero emissions in transportation, stationary or remote power, and portable power applications.
- Can be used for gigawatt-hours of long-term energy storage and as a “responsive load” on the grid to enable grid stability.
- Can be used in a variety of “hard to decarbonize” domestic industries, such as the manufacturing of steel, cement, ammonia, and other chemicals.

Uses of Green Hydrogen

- **Displacing natural gas in power generation.**
- **Transporting hydrogen through (existing) gas pipelines.**
- **Taking advantage of (excess) renewable energy.**
- **Meeting peak demand.**
- **Transportation and Cargo Handling Equipment.**

“Clean hydrogen is a game changer. It will help decarbonize high-polluting heavy-duty and industrial sectors, while delivering good-paying clean energy jobs and realizing a net-zero economy by 2050.”

US Department of Energy Secretary Granholm

Hydrogen Color Spectrum

GREEN

Hydrogen produced by electrolysis of water, using electricity from renewable sources like hydropower, wind, and solar. Zero carbon emissions are produced.

TURQUOISE

Hydrogen produced by the thermal splitting of methane (methane pyrolysis). Instead of CO_2, solid carbon is produced.

PINK/PURPLE/RED

Hydrogen produced by electrolysis using nuclear power.

BLACK/GRAY

Hydrogen extracted from natural gas using steam-methane reforming.

YELLOW

Hydrogen produced by electrolysis using grid electricity.

BLUE

Grey or brown hydrogen with its CO_2 sequestered or repurposed.

WHITE

Hydrogen produced as a byproduct of industrial processes.

BROWN

Hydrogen extracted from fossil fuels, usually coal, using gasification.

Note: There are no official definitions of these colors, but the above represents common industry nomenclature.

NACFE
NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

Today's Agenda

1:20 – 2:00 – Panel 1 – the Big Picture, Introduced and Moderated by JoAnn Milliken, Director, New Jersey Fuel Cell Coalition and Member, New Jersey Hydrogen Task Force

- Pete Devlin, Program Manager, Hydrogen & Fuel Cell Technologies Office, US Department of Energy
- Genevieve Saur, Senior Engineer, Transportation & Hydrogen Systems Center, National Renewable Energy Laboratory

2:00 – 3:00 – Panel 2 – Green Hydrogen Production and Distribution, Moderated by Barry Carr, Board Member, NJ Clean Cities

- Doug Copeland, Development Manager, Atlantic Shores Offshore Wind
- Kyle Nolan, Vice President of Innovation & Business Improvement, South Jersey Industries
- Roy Bant, Hydrogen Key Account Manager, Chart Industries

3:00 – 3:45 – Panel 3 – Green Hydrogen Use in New Jersey and Beyond, Moderated by Brian Keelen, Principal, Air & Gas Technologies and Board Member, NJ Clean Cities

- Charlie Myers, President, MA Hydrogen Coalition
- Bill Zobel, Executive Director, California Hydrogen Business Council
- Mike Strizki, Executive Director, NJ Hydrogen House Project

3:45 – 4:00 Wrap-up and Next Steps, Chuck and JoAnn

Contact Information

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NJ Green Hydrogen Forum

Panel 1: The Big Picture

Moderator: JoAnn Milliken, NJFCC
Speakers: Peter Devlin, USDOE
Genevieve Saur, NREL

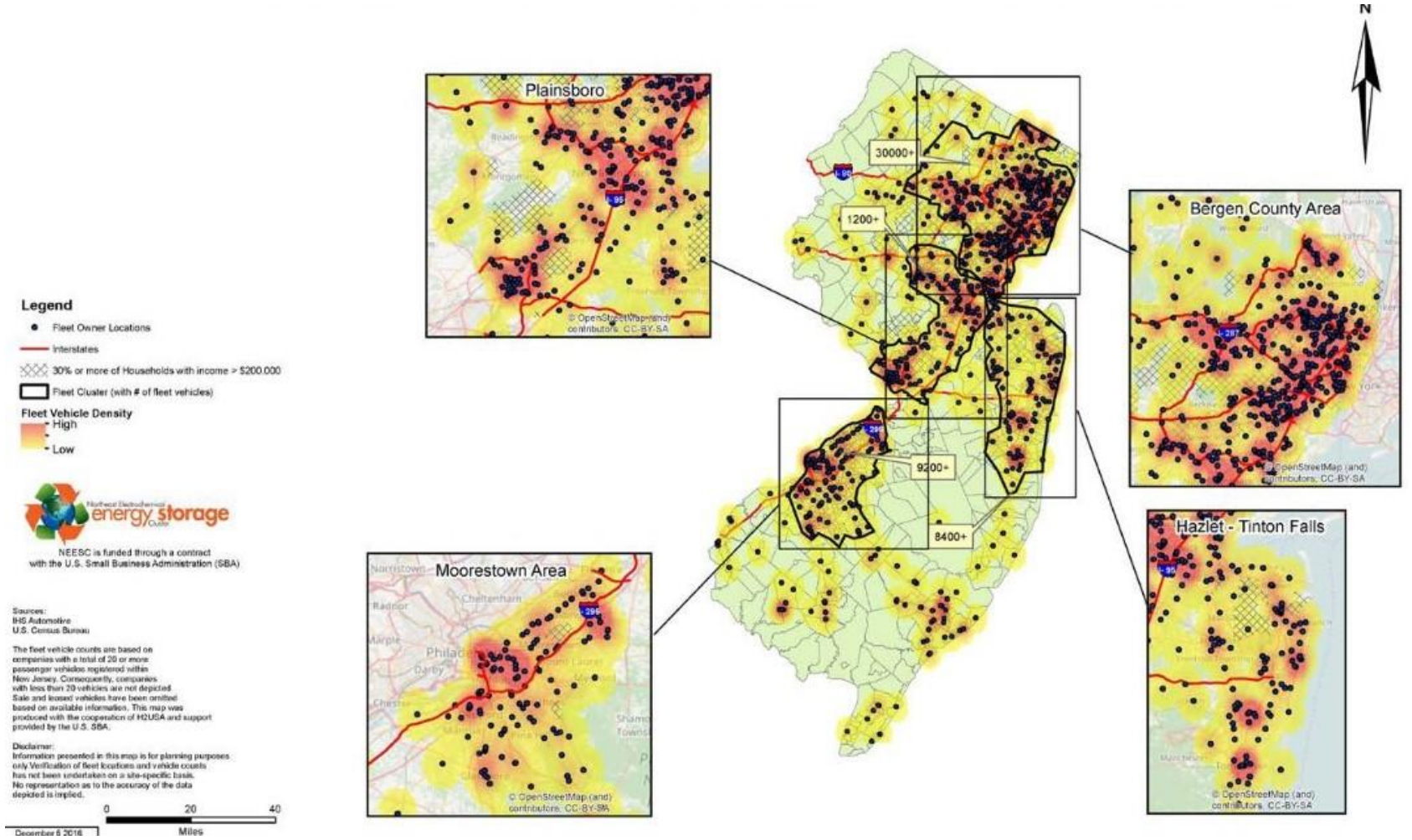
NJFCC
NEW JERSEY FUEL CELL
COALITION

New Jersey Fuel Cell Coalition

Ad Hoc group of industry, academic, and government leaders working collectively to strengthen New Jersey's fuel cell and hydrogen industries, and to assist the State in meeting its clean energy and energy resiliency goals

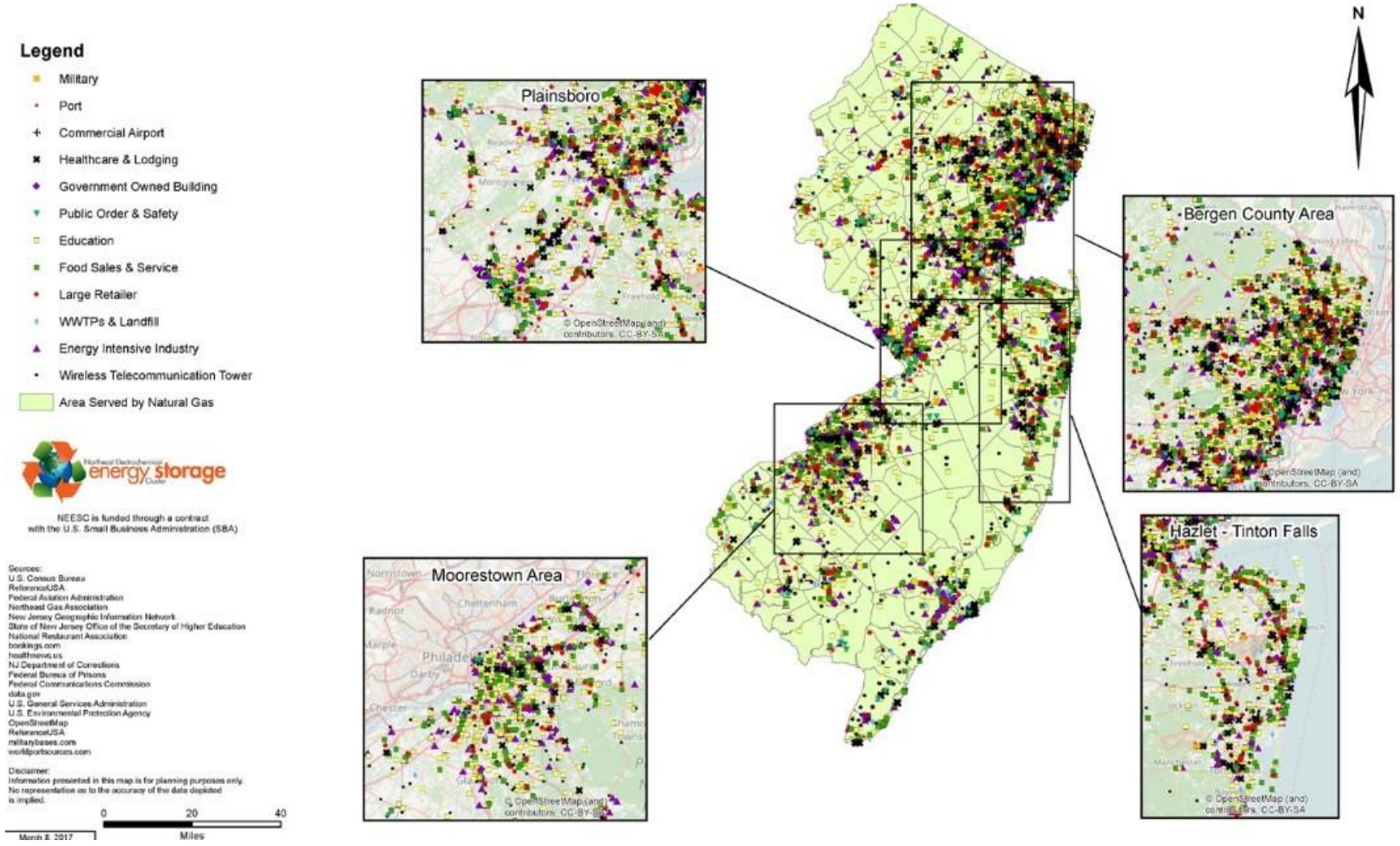
https://njfuelcells.org

New Jersey Market Potential:
Hydrogen and Fuel Cell Transportation Applications



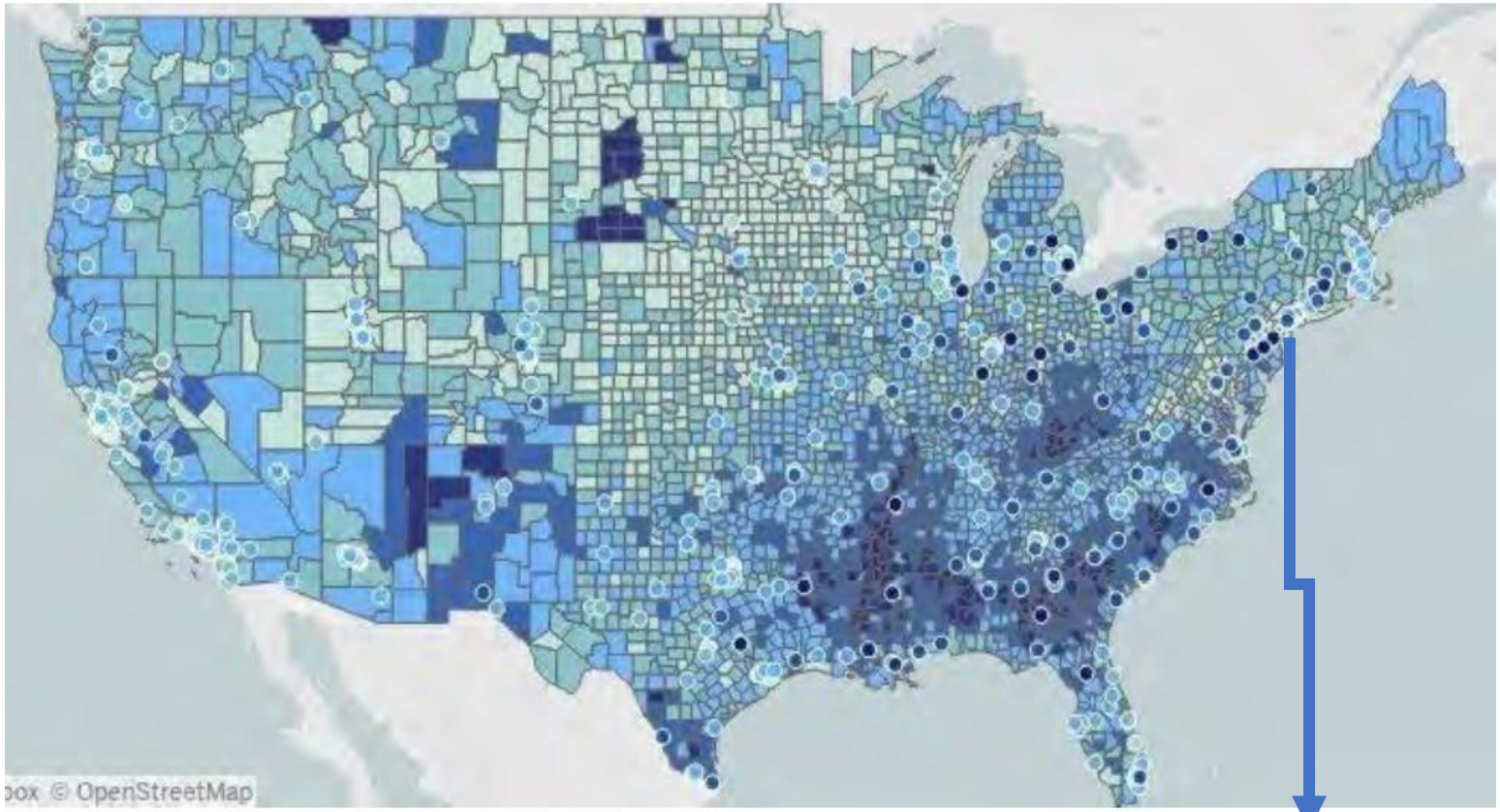
http://neesc.org/wp-content/uploads/2015/01/2018_NJ_H2_Fuel_Cell_Dev_Plan_final4.pdf

New Jersey Market Potential:
Hydrogen and Fuel Cell Stationary Applications



http://neesc.org/wp-content/uploads/2015/01/2018_NJ_H2_Fuel_Cell_Dev_Plan_final4.pdf

Environmental Justice for New Jersey Underserved Communities



New index ranks America's 100 most disadvantaged communities | University of Michigan News (umich.edu)

Trenton, Camden, Newark, Cumberland County

DOE Hybrid/Integrated Energy Projects – Let's add New Jersey to the list …

Hybrid/Integrated Energy Systems

Offering economic opportunities with environmental benefits across the U.S.

H_2 for Marine Application

California

1st-of-its-kind maritime H_2 refueling on floating barge - up to ½ ton H_2 /day

H_2 from Renewables

Texas

Integrates wind, solar, RNG from waste with onsite electrolysis and multiple end-uses

H_2 for Data Center

Washington

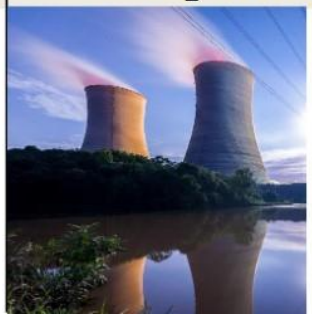
Integrates a 1.5MW fuel cell with a data center to provide reliable and resilient power

H_2 for Steel Production

Missouri

Reduction of 30% in energy and 40% emissions vs. conventional processes

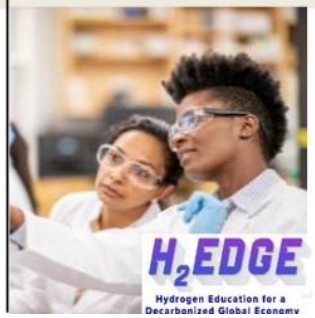
H_2 from Nuclear



New York

Demonstrates a MW electrolyzer with a nuclear plant (collaboration with Nuclear Office)

Workforce Development



Multi-state

A Training, education and recruiting program to build skills needed in the H_2 industry

New Jersey
Fuel Cell Task Force

- In June 2020, New Jersey's Fuel Cell Task Force Bill (S762/A741*) signed into law by Governor Phil Murphy.
- Members appointed in January 2021 and began their work, led by NJBPU, in April.
- Identify opportunities for New Jersey to realize the benefits of hydrogen and fuel cell technologies in helping the State meet its goal of 100 percent clean energy by 2050.
- Submit findings, including recommendations for legislative or regulatory actions, to the Governor and Legislature by May 2022.

* Primary sponsors of the bill: Assemblymen Gordon Johnson, Herb Conaway, and Andrew Zwicker; Senators Vin Gopal and Joseph Lagana. Co-sponsored by six additional Assembly Members and one other Senator.

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office Perspectives

Pete Devlin

Hydrogen and Fuel Cell Technologies Office

New Jersey Green Hydrogen Forum 2021

June 29, 2021

President's Plan for a Clean Energy Economy: 9 Key Elements

1. **Take executive action** on Day 1
2. Enact an irreversible path to **economy-wide net-zero emissions by 2050**
3. **Act and lead globally**
4. **Public investment in clean energy** and innovation
5. **Accelerate the deployment of clean technology** throughout our economy
6. **Make environmental justice a priority** for all federal agencies
7. **Require public companies to disclose climate risks** and GHG emissions
8. **Create millions of good-paying jobs** with the choice to join a union
9. **Fulfill our obligation to communities** and workers that have risked their lives to produce fossil fuels

100% carbon-pollution-free electric sector by 2035

from Executive Order on
Tackling the Climate Crisis signed Jan 27, 2021

whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/


Hydrogen Energy Earthshot
"Hydrogen Shot"
Launched June 7, 2021

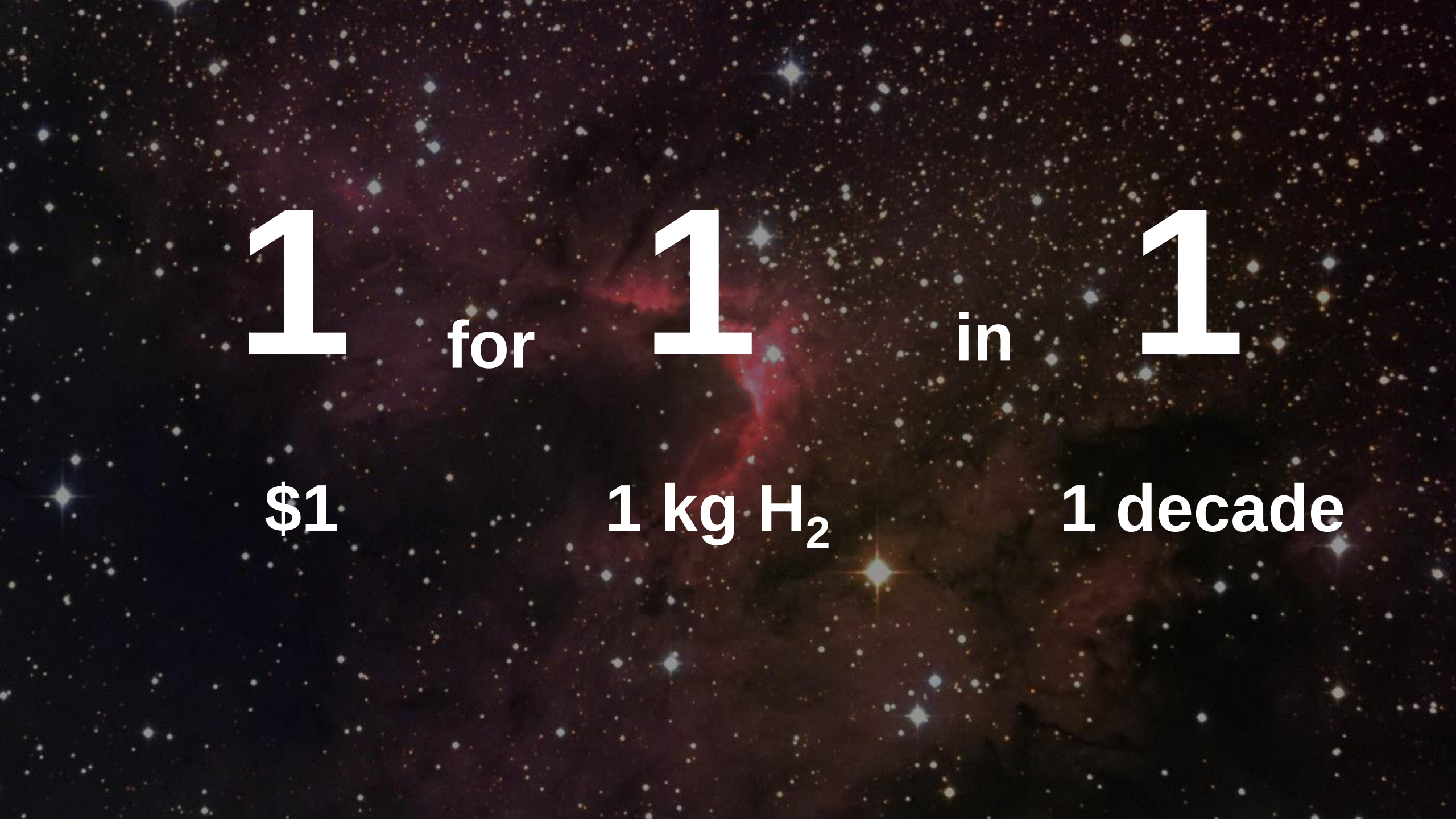
President Biden and Energy Secretary Granholm at Climate Summit

"…I've asked the Secretary of Energy to speed the development of critical technologies to tackle the climate crisis. No single technology is the answer on its own because every sector requires innovation to meet this moment."

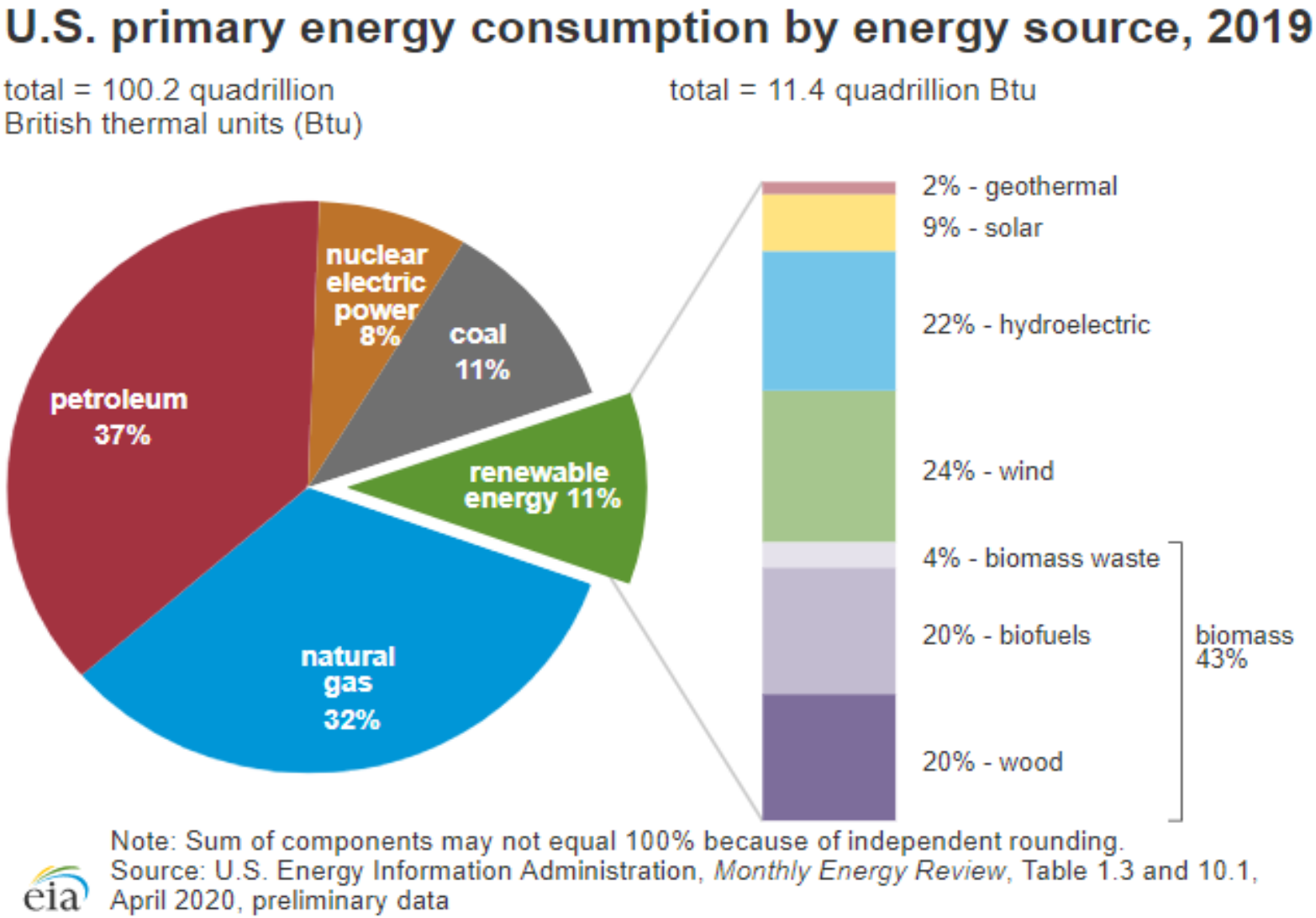
President Joseph R. Biden
April 23, 2021

Launch of Hydrogen Energy Earthshot
First of the Energy Earthshots
June 7, 2021
at DOE Hydrogen Program AMR

Secretary Jennifer Granholm
June 7, 2021


1 for 1 in 1
$1 1 kg H_2 1 decade

U.S. Energy Landscape and Key Goals



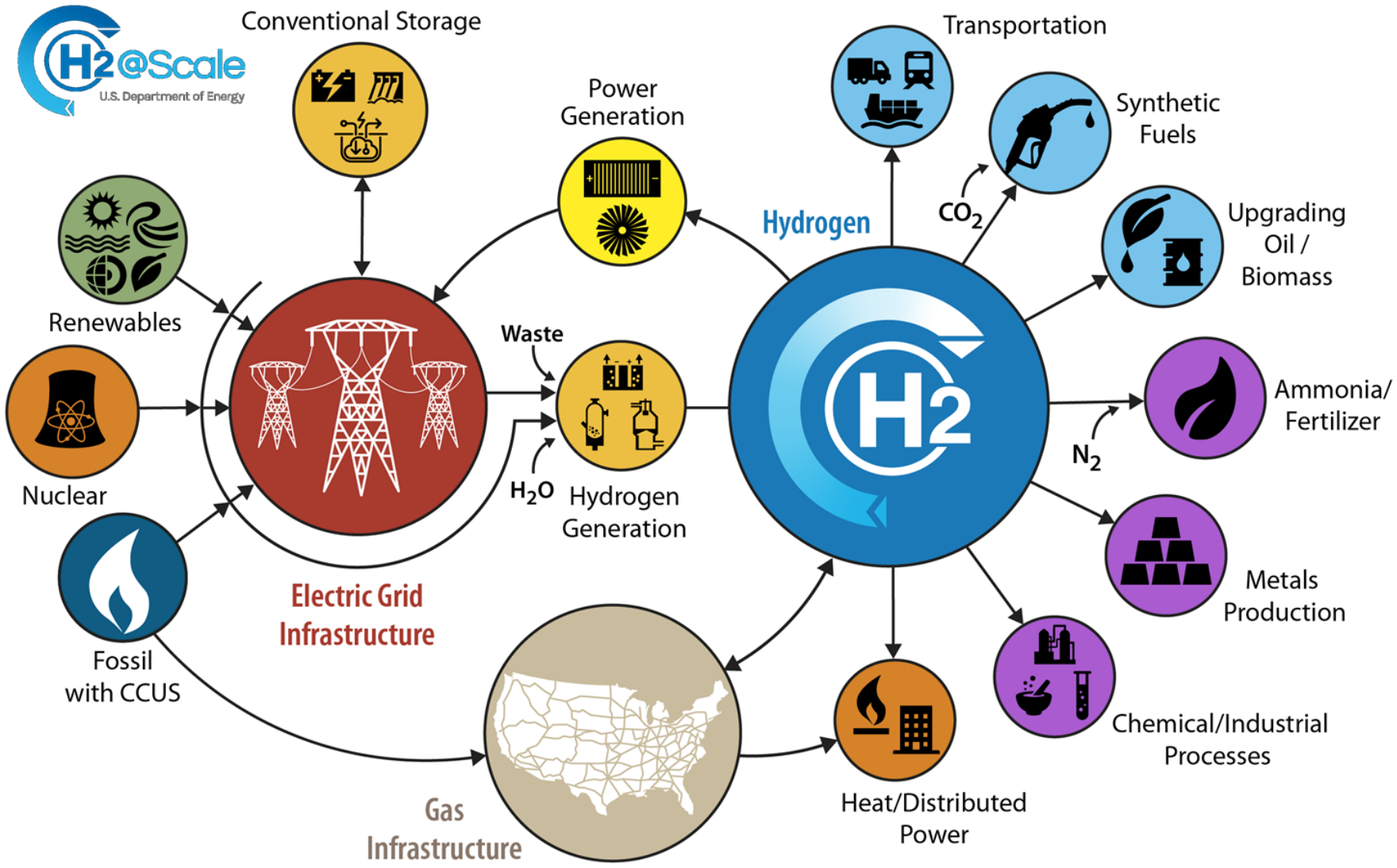
Administration Goals include:

- 100% carbon-pollution-free electric sector by 2035
- Net zero emissions economy by 2050

Priorities: Ensure benefits to all Americans, focus on jobs, EJ40: 40% of benefits in disadvantaged communities

EJ: Environmental Justice

H2@Scale Opportunities: Deep Decarbonization, Economic Growth, Jobs



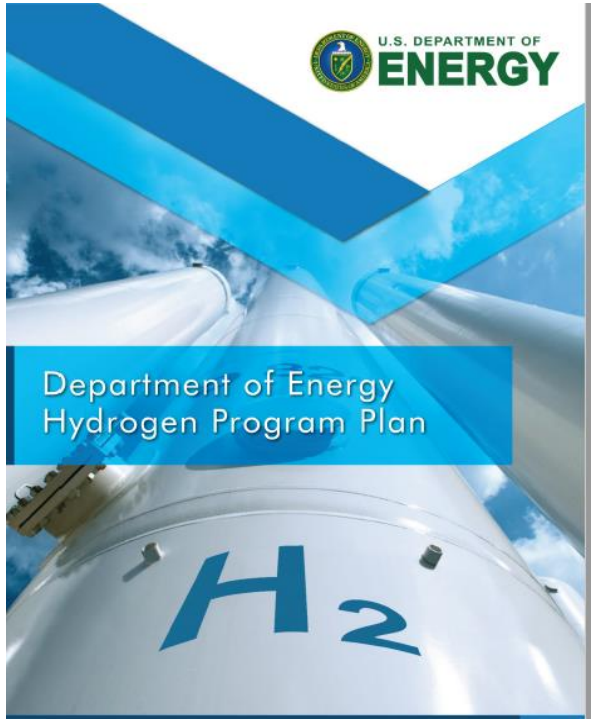
Potential

- 10 MMT of H_2/yr produced today with scenarios for ~5X growth
- 10 MMT H_2 would ~ double today's solar or wind deployment
- Industry study shows potential for $140B in revenue, 700K jobs, 16% GHG reduction. Analysis underway, including on export potential.

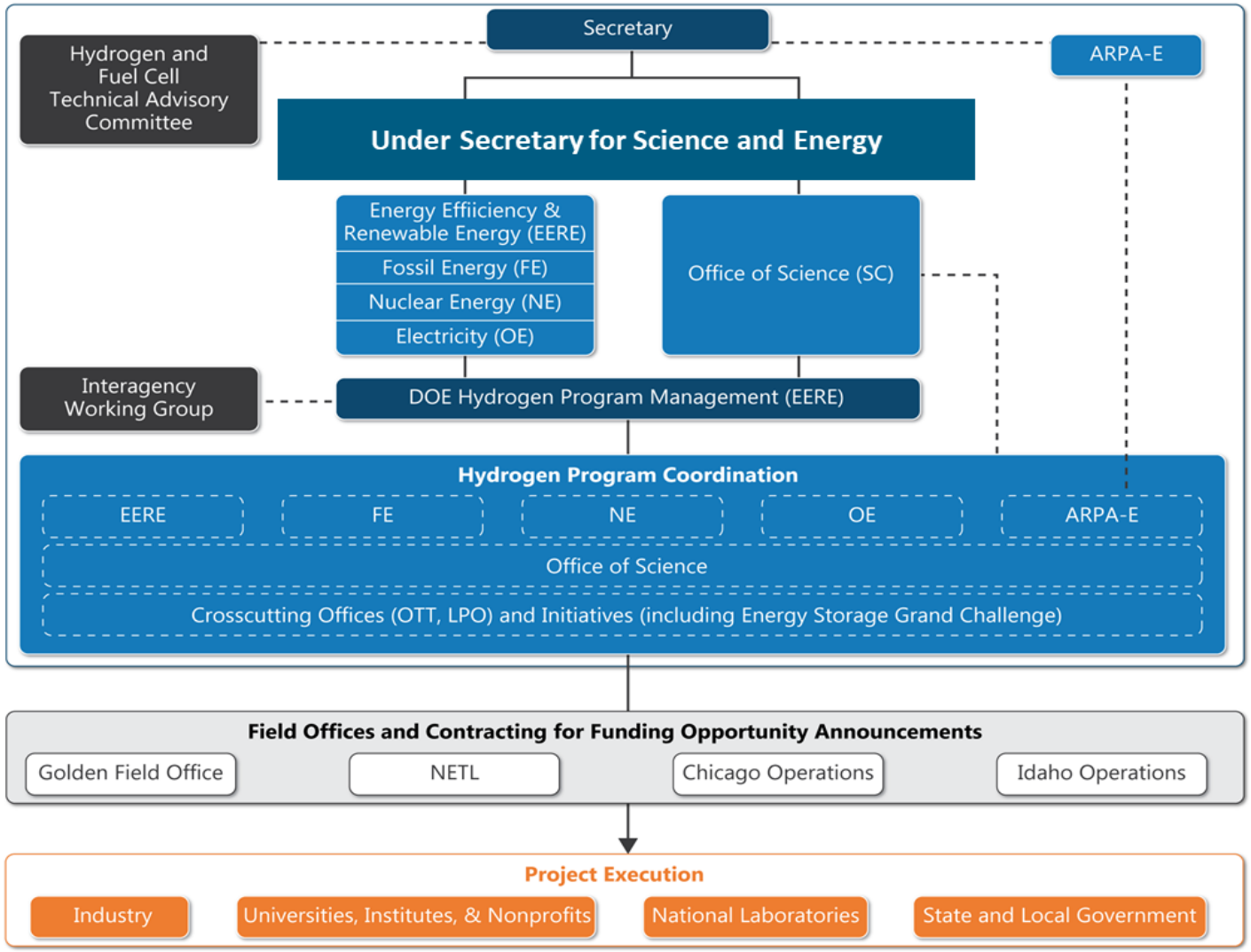
The U.S. DOE Hydrogen Program Released November 2020

The Energy Policy Act (2005) Title VIII and Energy Policy Act of 2020 provide key authorization

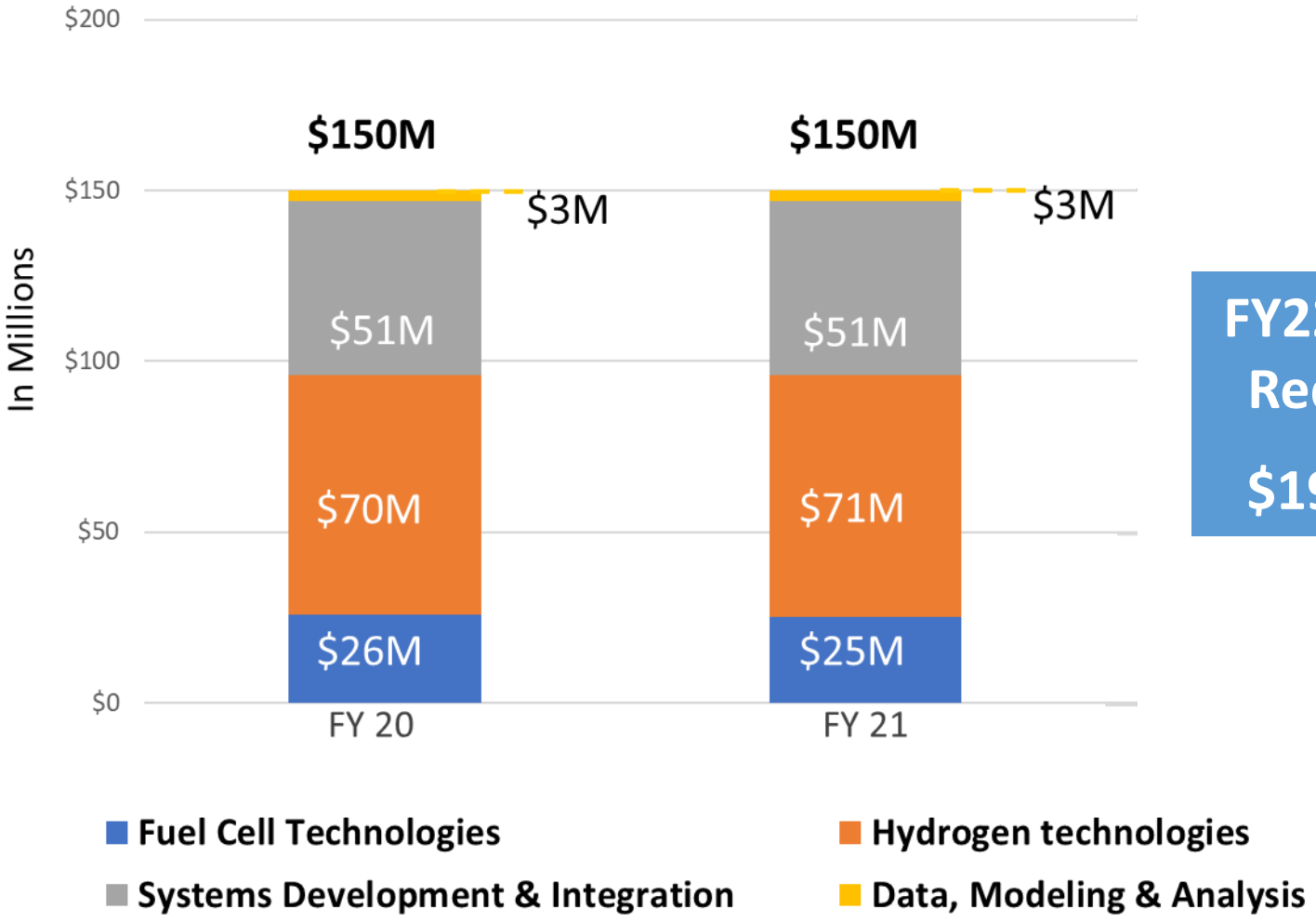
Hydrogen is one part of a broad portfolio of activities



www.hydrogen.energy.gov



Funding for Hydrogen and Fuel Cell Technologies Office (HFTO)



FY22 HFTO Request:

$197.5M

HFTO has funded over 190 companies, 109 universities, and 16 National Labs across 40 States over the last decade

Program Enabled Accomplishments

Innovation

1,100 Patents

in hydrogen and fuel cell technologies through HFTO funding from Labs, Industry and Academia

35% from National Labs

Technology-to-Market

30 Technologies Commercialized

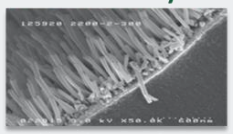
By private industry

65 With Potential to Enter Market

in the next 3-5 years

Examples of Technologies Enabled

Fuel Cell Catalysts



Catalyst and Supports for PEM Fuel Cells
3M

Hydrogen Tube Trailers

Hydrogen Tube Trailers
Hexagon Lincoln

Forklifts

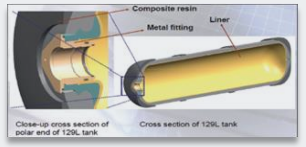
Class-1, -2, and -3 Forklifts
Plug Power (GenDrive FCs)

Electrolyzers

Electrolyzer System
Proton Series

PEM Electrolyzer System
Giner

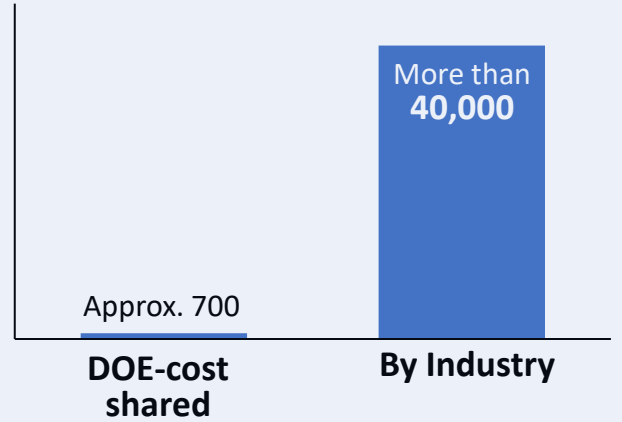
Hydrogen Tanks



Optimized 129L Tank
Quantum Technologies

Market Uptake

Hydrogen fuel cell forklifts in the U.S.



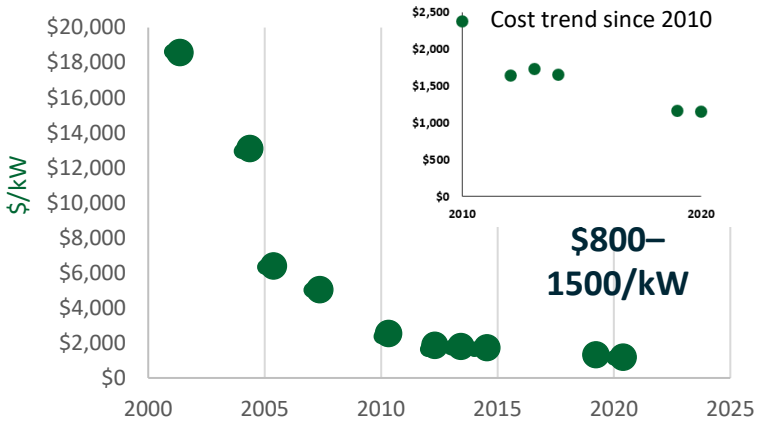
American-made small-scale hydrogen refueler

- Exported to Japan
- Uses electrolysis

Program-funded Progress But More Work is Needed

Hydrogen Production
(PEM electrolyzer- low volume)

Cut cost by 90% since 2005

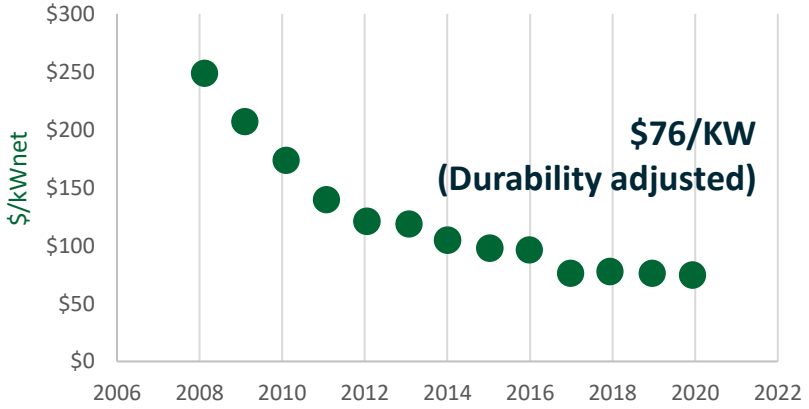


Note: 2010 to 2018-zero/limited HFTO funding on electrolysis
PEM: Polymer Electrolyte Membrane

Need ~ 80% cost reduction to $250-$300/kW

Fuel Cells
(Automotive PEM fuel cell system- 100K/yr)

Cut cost by 70% since 2008

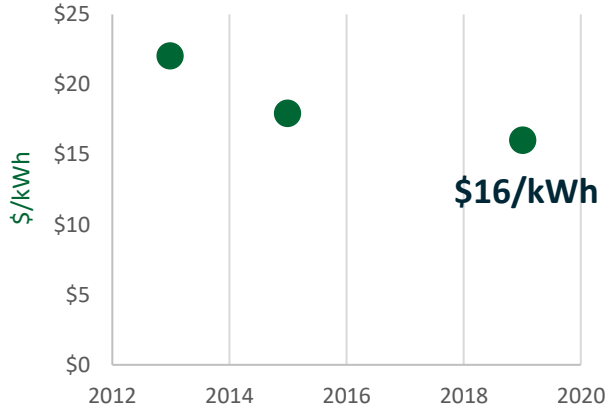


Note: At 100k systems/year

Need 60% cost reduction to $80/kW for HD Trucks

Hydrogen Storage
(Carbon fiber 700 bar tanks- 100K/yr)

Cut cost by 30% since 2013



Note: At 100k units/year

Need 50% cost reduction to $8/kWh

Snapshot of Hydrogen and Fuel Cell Applications in the U.S.

Examples of Applications Deployed

- **>500MW** Backup Power
- **>40,000** Forklifts
- **>172 MW** PEM* Electrolyzers
- **>60** Fuel Cell Buses
- **>45** H_2 Retail Stations
- **~10,000** Fuel Cell Cars

*Polymer electrolyte membrane

Major Hydrogen Production Sites

0 – 50
50 – 100
100 – 200
200 – 400
400 – 800

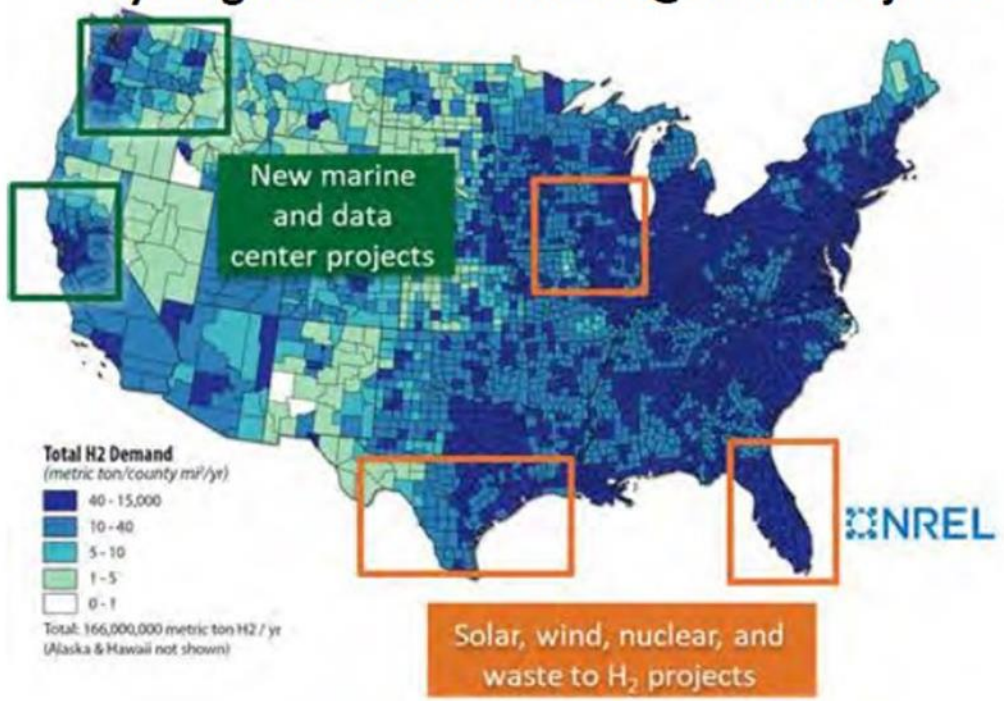
Hydrogen Production Units
Gaseous Metric Tons/Day

- 10 million metric tons produced annually
- More than 1,600 miles of H_2 pipeline
- World's largest H_2 storage cavern

Hydrogen Stations Plans Across States

California	Northeast	
200 Stations Planned	12 – 20	HI, OH, SC, NY,
California Fuel Cell	Stations	CT, MA, CO, UT,
Partnership Goal	Planned	TX, MI
		And Others

Hydrogen Demand and H2@Scale Projects



Example of Success Story: Fuel Cell Forklifts for Material Handling Applications

Fuel Cell Stationary Power for Multiple Applications

Fuel cells provided backup power during Hurricane Sandy in the U.S. Northeast

Fuel cells included for power to new World Trade Center in NYC

Fuel cell power for maritime ports demonstrated in Honolulu, Hawaii

Over 500 MW of fuel cell stationary power installed across more than 40 US states

Heavy Duty Applications Emerging

Several companies developing long haul Class 8 fuel cell trucks

Fuel cell buses in CA surpass 20M passengers

High-speed fuel cell ferry under development in the US

Fuel cell parcel truck demonstration projects by DOE + industry

Fuel cell delivery truck projects by DOE + industry

Fuel cell commuter rail in being developed in the US (CA)

Examples of H2@Scale Projects to Demonstrate Technology and Train Future Workforce

Different regions, hydrogen sources, end uses & educational opportunities

H_2 for Marine Application

California

1st-of-its-kind maritime H_2 refueling on floating barge - up to ½ ton H_2/day

H_2 from Renewables

Texas

Integrates wind, solar, RNG from waste with onsite electrolysis and multiple end-uses

H_2 for Data Center

Washington

Integrates a 1.5MW fuel cell with a data center to provide reliable and resilient power

H_2 for Steel Production

Missouri

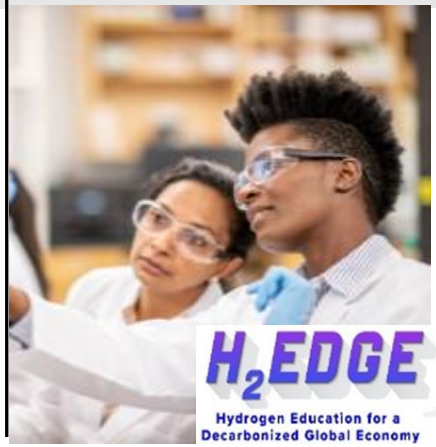
Reduction of 30% in energy and 40% emissions vs. conventional processes

H_2 from Nuclear

Eastern US

Demonstrates a MW electrolyzer with a nuclear plant
(collaboration with Nuclear Office)

Workforce Development



Multi-state

A Training, education and recruiting program to build skills needed in the H_2 industry

Financing to Enable Deployment at Scale

Loan Programs Office

$40 Billion in Available Debt Capital

LPO offers project financing across energy sectors through three distinct loan programs.

Includes Clean Hydrogen

TITLE 17
Innovative Energy Loan Guarantees

- **Advanced Fossil Energy** — $8.5 Billion Available
- **Advanced Nuclear Energy** — $10.9 Billion Available
- **Renewable Energy & Efficient Energy** — Up to $4.5 Billion Available

ATVM
Direct Loans

- **Advanced Technology Vehicle Manufacturing** — $17.7 Billion Available

TELGP
Partial Loan Guarantees

- **Tribal Energy Projects** — Up to $2 Billion Available

Jigar Shah joins DOE as LPO Director

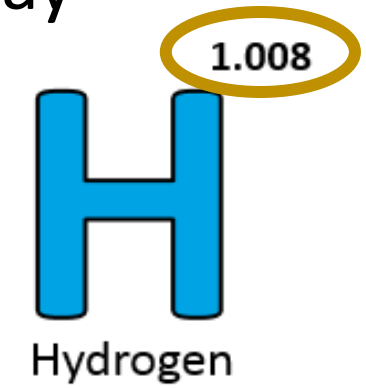
For more information: lpo@hq.doe.gov or Monique.Fridell@hq.doe.gov

HFTO connects with stakeholders through events, webinars, website resources and communications activities

Hydrogen Energy Earth Shot Requests for Information DE-FOA-0002529: Hydrogen Demonstrations on abundant, affordable clean hydrogen solutions within the decade.
https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office-funding-opportunities

Oct 8 - Hydrogen and Fuel Cells Day

(Held on its very own atomic weight-day)



Resources

INCREASE YOUR H2IQ

Join Monthly
H2IQ Hour Webinars

Download
H2IQ For Free

energy.gov/eere/fuelcells/fuel-cell-technologies-office-webinars

energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource

Visit H2tools.Org
for hydrogen safety and lessons learned
https://h2tools.org/

Learn more:

Sign up to receive hydrogen and fuel cell updates
www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter

Learn more at: energy.gov/eere/fuelcells AND www.hydrogen.energy.gov

Thank You

Pete Devlin
Peter.Devlin@ee.doe.gov

www.energy.gov/fuelcells
www.hydrogen.energy.gov

Integrating Hydrogen Systems at NREL

Genevieve Saur
National Renewable Energy Laboratory

NJ Clean Cities Coalition

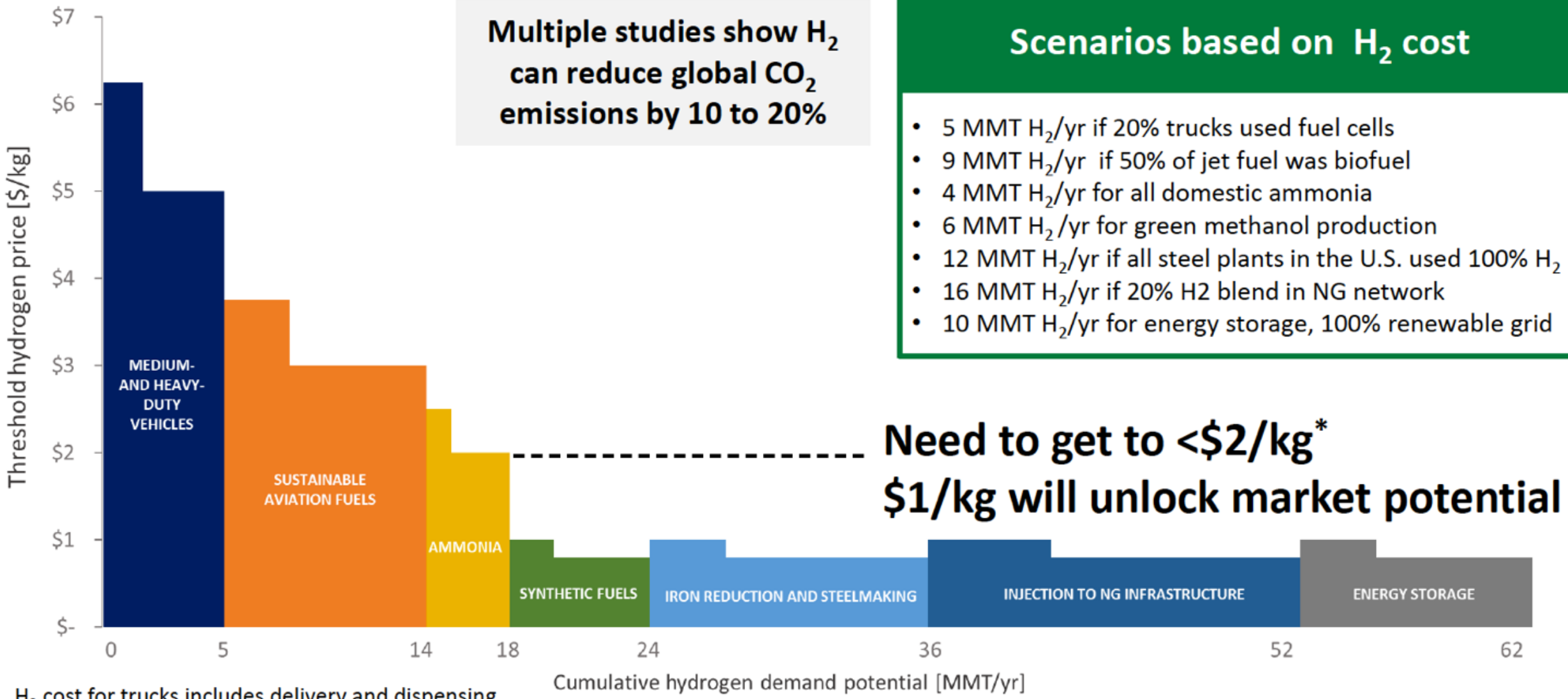
Sustainably-Produced (Green) Hydrogen Forum
June 29, 2021

Analysis Determines Market Potential Scenarios

Multiple studies show H_2 can reduce global CO_2 emissions by 10 to 20%

Scenarios based on H_2 cost

- 5 MMT H_2/yr if 20% trucks used fuel cells
- 9 MMT H_2/yr if 50% of jet fuel was biofuel
- 4 MMT H_2/yr for all domestic ammonia
- 6 MMT H_2/yr for green methanol production
- 12 MMT H_2/yr if all steel plants in the U.S. used 100% H_2
- 16 MMT H_2/yr if 20% H2 blend in NG network
- 10 MMT H_2/yr for energy storage, 100% renewable grid



**Need to get to <$2/kg*
$1/kg will unlock market potential**

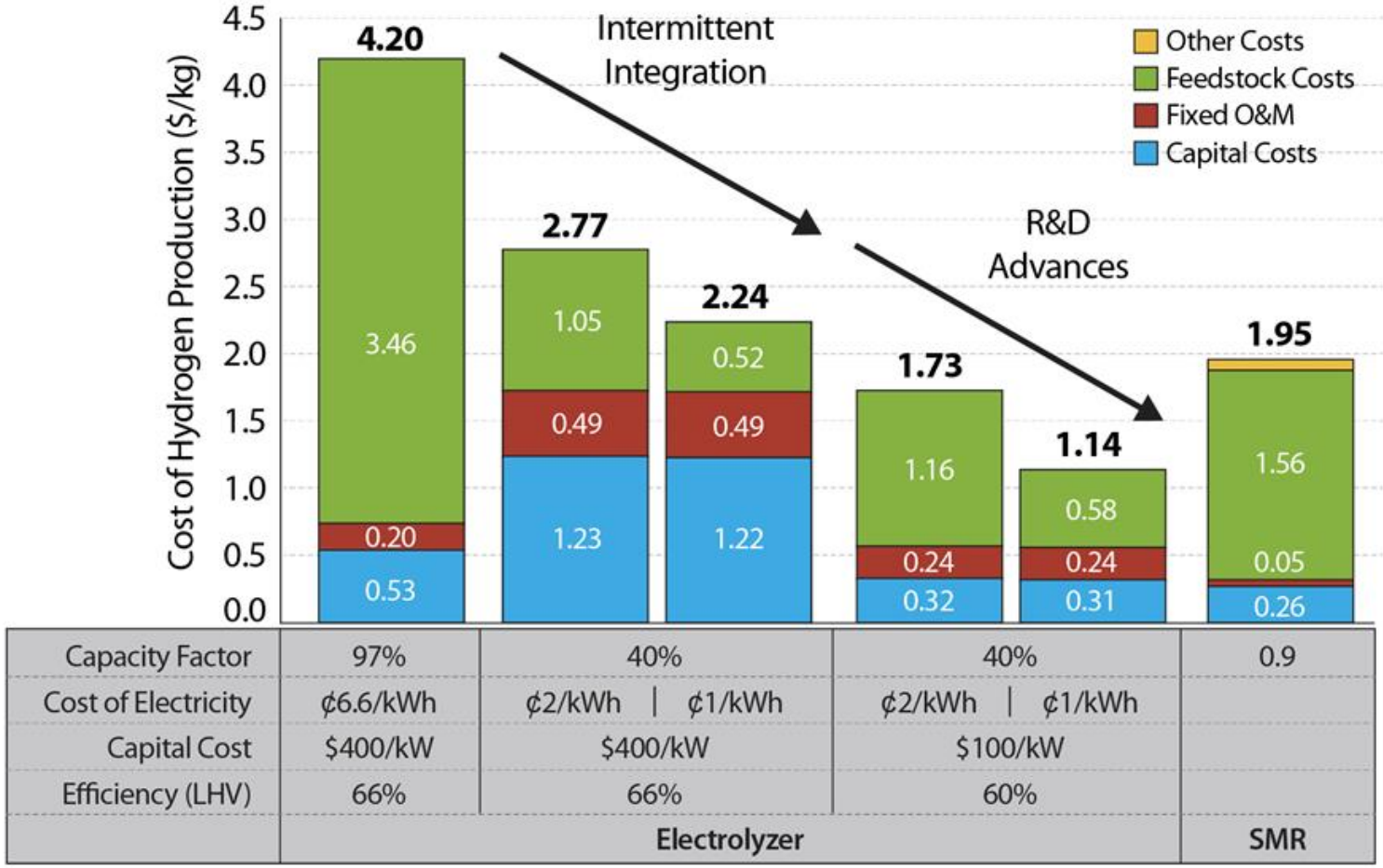
H_2 cost for trucks includes delivery and dispensing

* H_2 could compete at $1 to $2/kg higher cost with a carbon price

Results based on preliminary analysis

…but **only** if we can get the cost of green hydrogen down lower than from natural gas

Potential Levelized Costs of H_2 Production



Capacity Factor	97%	40%	40%	0.9
Cost of Electricity	¢6.6/kWh	¢2/kWh | ¢1/kWh	¢2/kWh | ¢1/kWh	
Capital Cost	$400/kW	$400/kW	$100/kW	
Efficiency (LHV)	66%	66%	60%	
	Electrolyzer			SMR

The availability of low-cost, dispatch constrained electricity (LDE) provides an opportunity for hydrogen production, providing electrolyzer capital costs can be reduced sufficiently.

Source: Bryan Pivovar & Josh Eichman

H2@Scale Analysis: Serviceable Consumption Potential

Serviceable Consumption Potential of hydrogen market by 2050 is >10X.

Other applications are possible based on technology and policy growth as well as smaller applications

Application	Serviceable Consumption Potential (MMT/yr)	2015 Market for On-Purpose H2 (MMT/yr)
Refineries and the chemical processing industry (CPI) [a]	7	6
Metals	12	0
Ammonia	4	3
Biofuels	9	0
Synthetic hydrocarbons	14	1
Natural gas supplementation	16	0
Seasonal energy storage for the electricity grid	15	0
Industry and Storage Subtotal	**77**	**10**
Light-duty fuel cell electric vehicles (FCEVs)	21	0
Medium- & Heavy-Duty FCEVs	8	0
Transportation Fuel Subtotal	**29**	**0**
Total	**106**	**10**

Definition: The Serviceable Consumption Potential is the estimated market size constrained by the services for which society currently uses energy, real-world geography, system performance, and by optimistic market shares but not by economic calculations.

NREL Strategy for Green Hydrogen Challenges

Make

Move

Store

Use

NREL Consortium Approach

Make
- **H2NEW** launched October 2020 (NREL leads)
- **HydroGEN 2.0** renewed for another 3 years in October 2020 (NREL leads)
- Work with private sector (SPP)

Move
- **HyBlend** consortium launched Nov. 2020 (NREL leads)
- Discussing new SPP work with several utilities
- **HyMARC** working on energy carriers

Store
- **HyMARC** consortium for better on-board and off-board H2 storage materials (NREL co-leads)
- Stationary storage not as demanding as vehicle app. (volume & mass)

Use
- Pivot from focus on LD alone to emphasis on HD FC trucks
- **Million Mile FC Truck** and **ElectroCAT 2.**0 launched Oct. 2020
- New projects on steel production using H2
- E2M

Subprograms

Make
- Hydrogen Production

Move
- Technology Validation
- Infrastructure, including **ARIES** capability build-out and industry projects

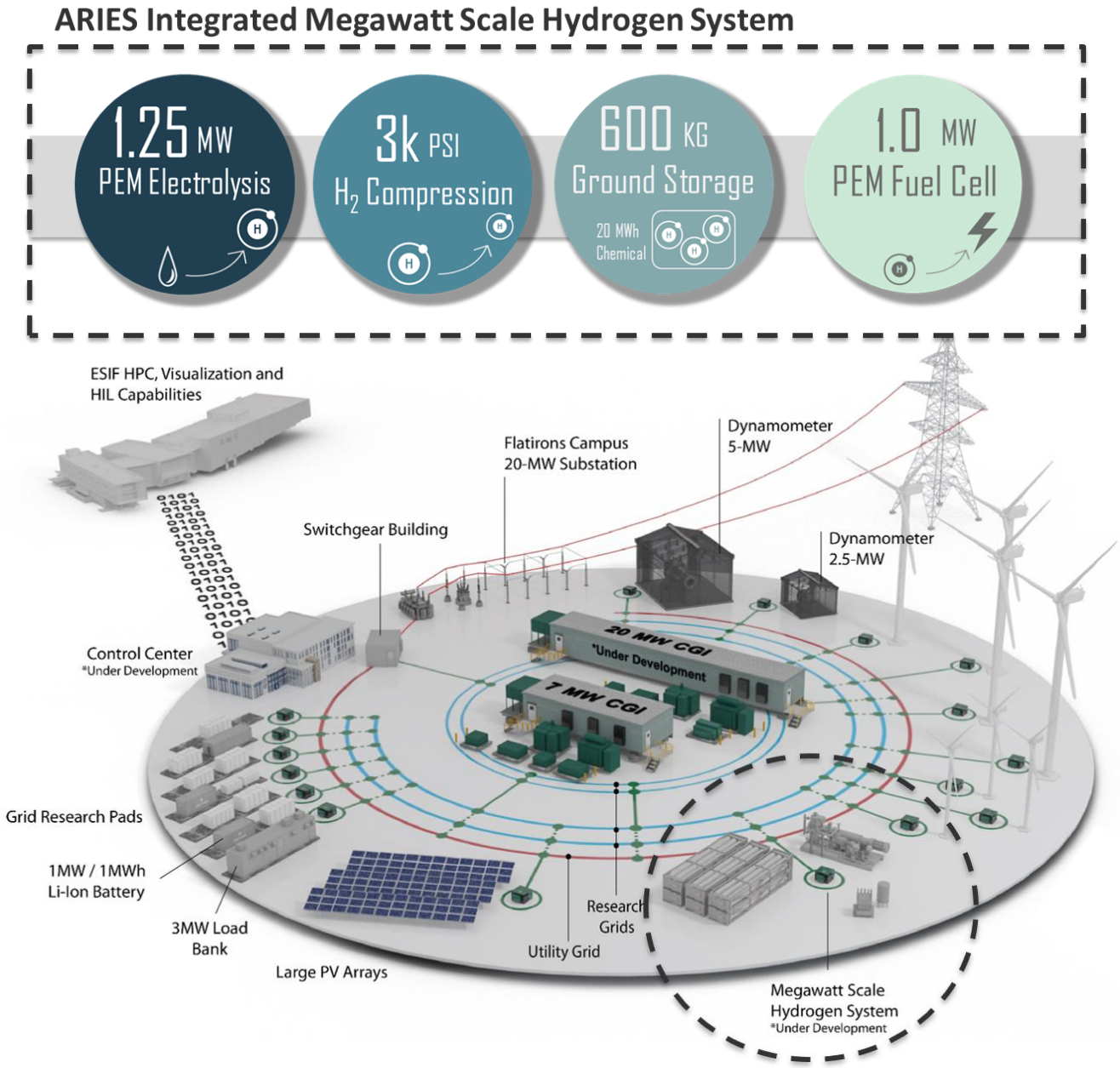
Store
- Hydrogen Storage

Use
- Fuel Cells

Crosscutting:
- Analysis
- Manufacturing
- Codes & Standards
- Prog. Mgmt

NREL is constructing a megawatt-scale hydrogen production, storage, and fuel cell at Flatirons Campus

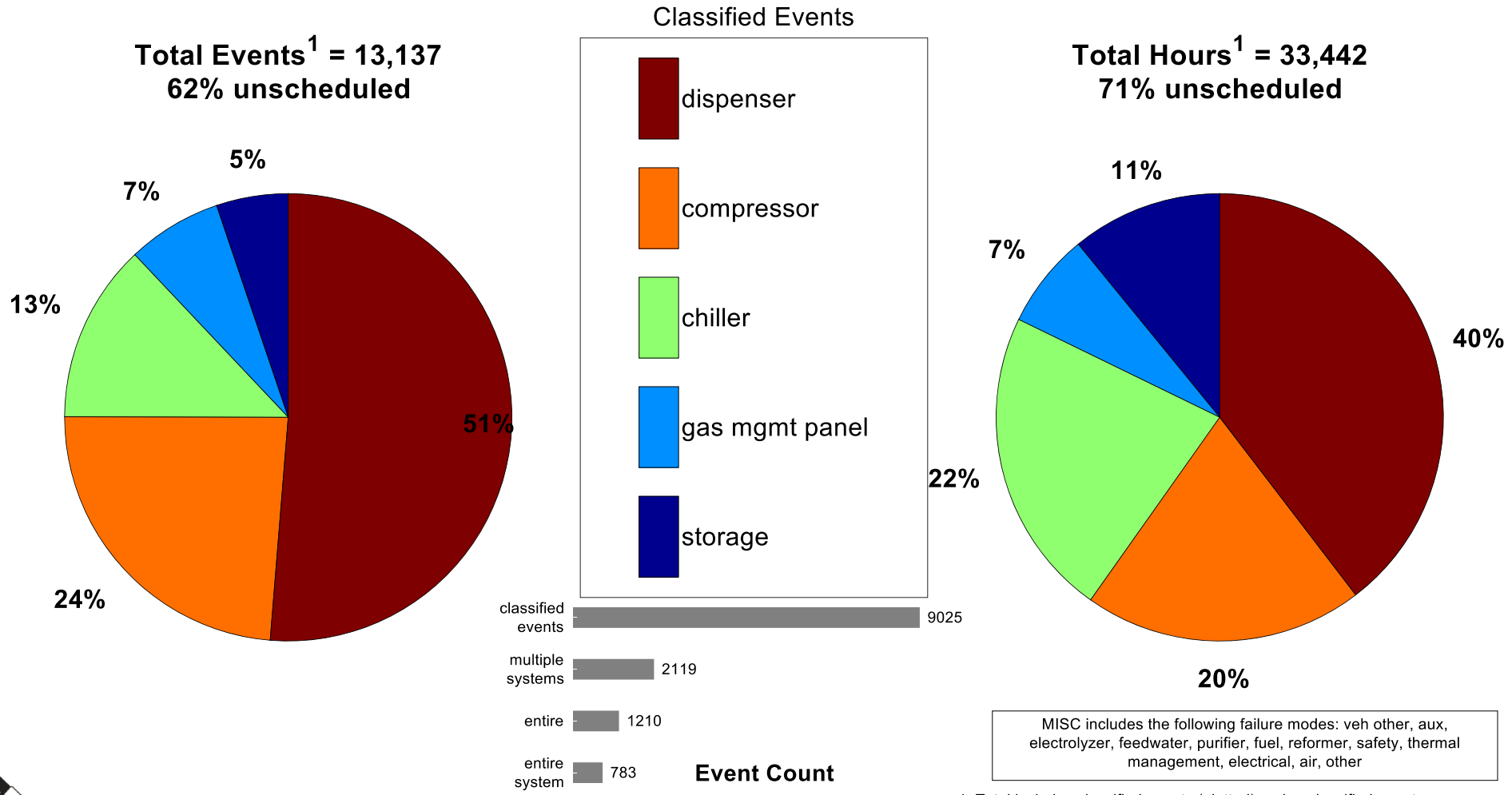
- ARIES: Advanced Research on Integrated Energy Systems
- The combined hydrogen system is expected to be installed, integrated with the high-level controller, and operational by the end of 2021.
- A larger permanent concrete research pad will be poured in FY22 and the system will be moved to the permanent location thereafter, allowing for capability expansion activities in the future.
- Future improvements are to include NG/H2 blending, H2/NG turbine, HD H2 refueling and compression for 10+ kg/min



H2 Refueling Station Data

102 Composite Data Products in 8 topic areas publicly available
https://www.nrel.gov/hydrogen/hydrogen-infrastructure-analysis.html

Maintenance by Known Equipment Type - Retail Stations[2]



NREL cdpRETAIL_infr_21
Created: Dec-07-20 4:43 PM | Data Range: 2014Q3-2020Q2

1. Total includes classified events (plotted) and unclassified events.
2. Maintenance events with unknown equipment type excluded from plot.

Innovating Hydrogen Stations

H2@Scale CRADA Project, 50% HFTO 50% Industry Funded
Industry Partners: Shell, Air Liquide, Toyota, Honda

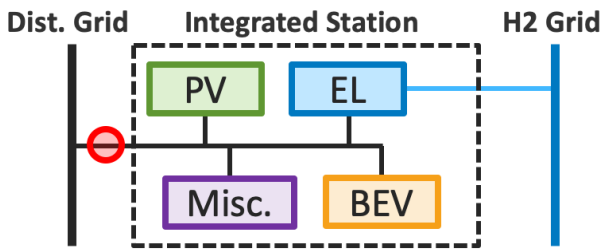
Goal: Comprehensive high flow rate fueling model validated with experimental data for 10 kg/min average fueling rate

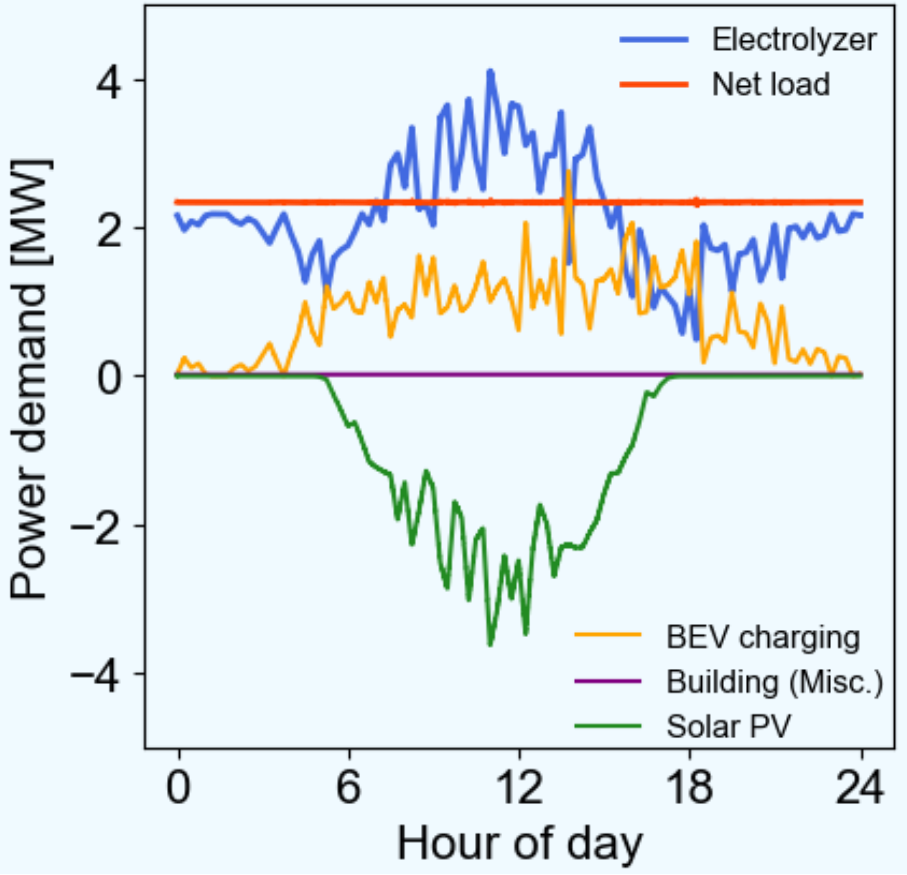
Experimental Capabilities Development at ESIF

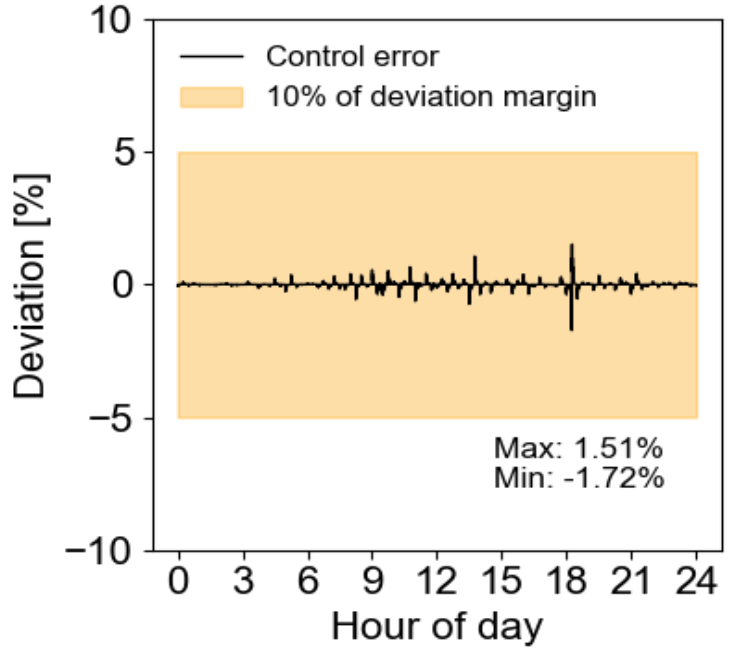
Electrolyzer Integration With BEV Fast Charge Station Provides Controllable Grid Load and Hydrogen Fuel – H2@Scale and ARIES activity

Real-time simulation demonstrates that ~5 MW electrolyzer stabilizes demands of ~3 MW BEV fast charge station integrated with large solar PV.

Real-time simulation analysis for high BEV demand scenario



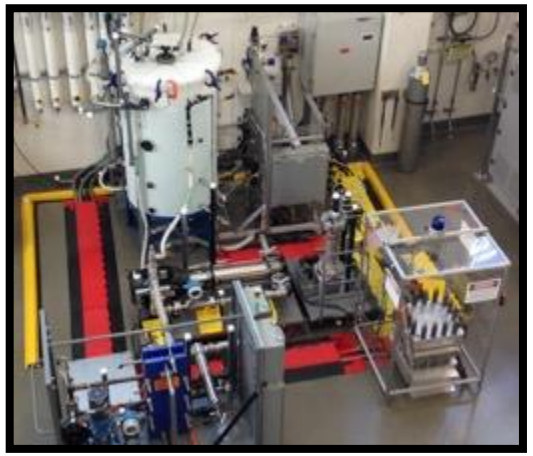


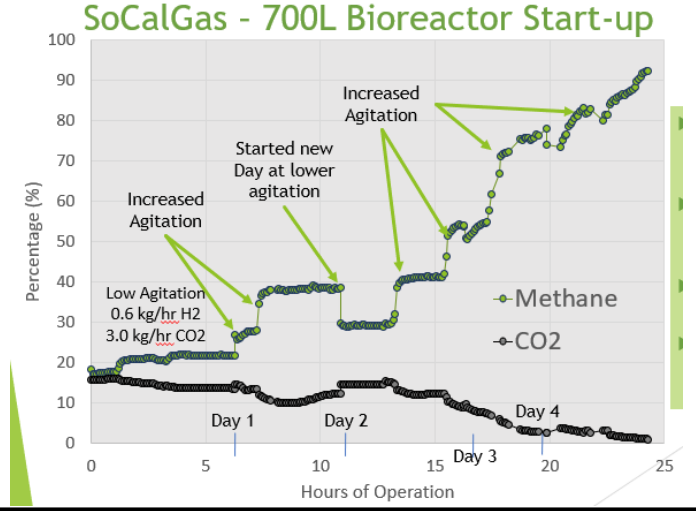


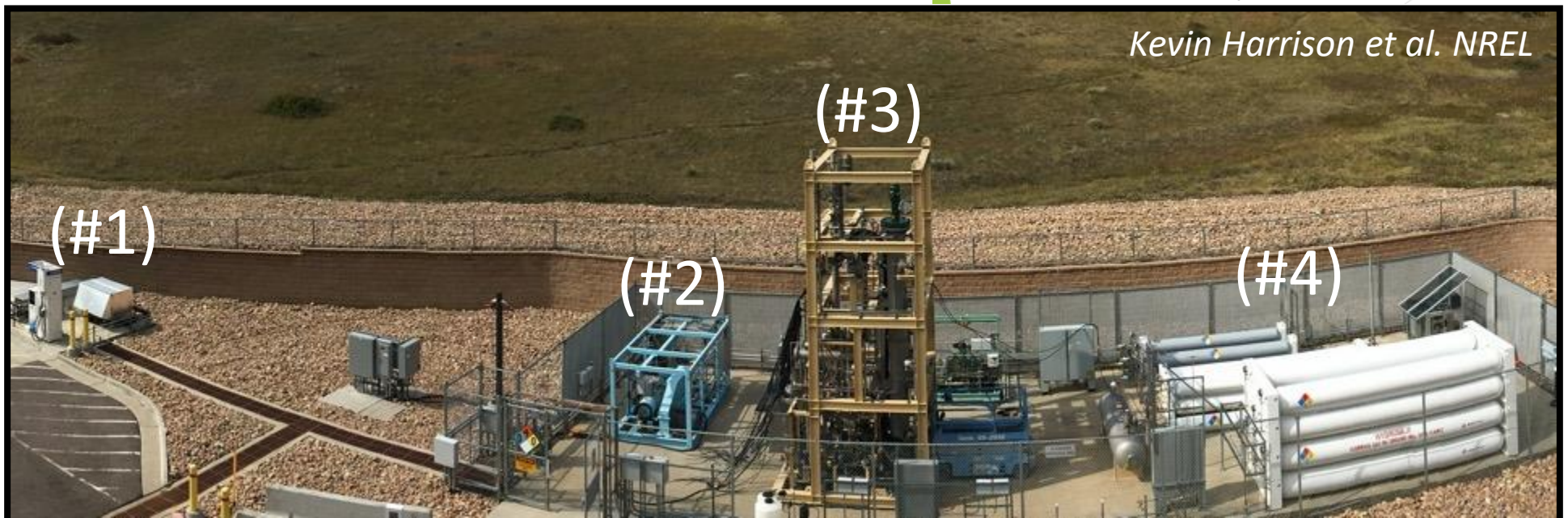
Source: National Renewable Energy Laboratory, 2020–2021

Example of E2M at Scale: Biomethanation with Electrolytic H_2

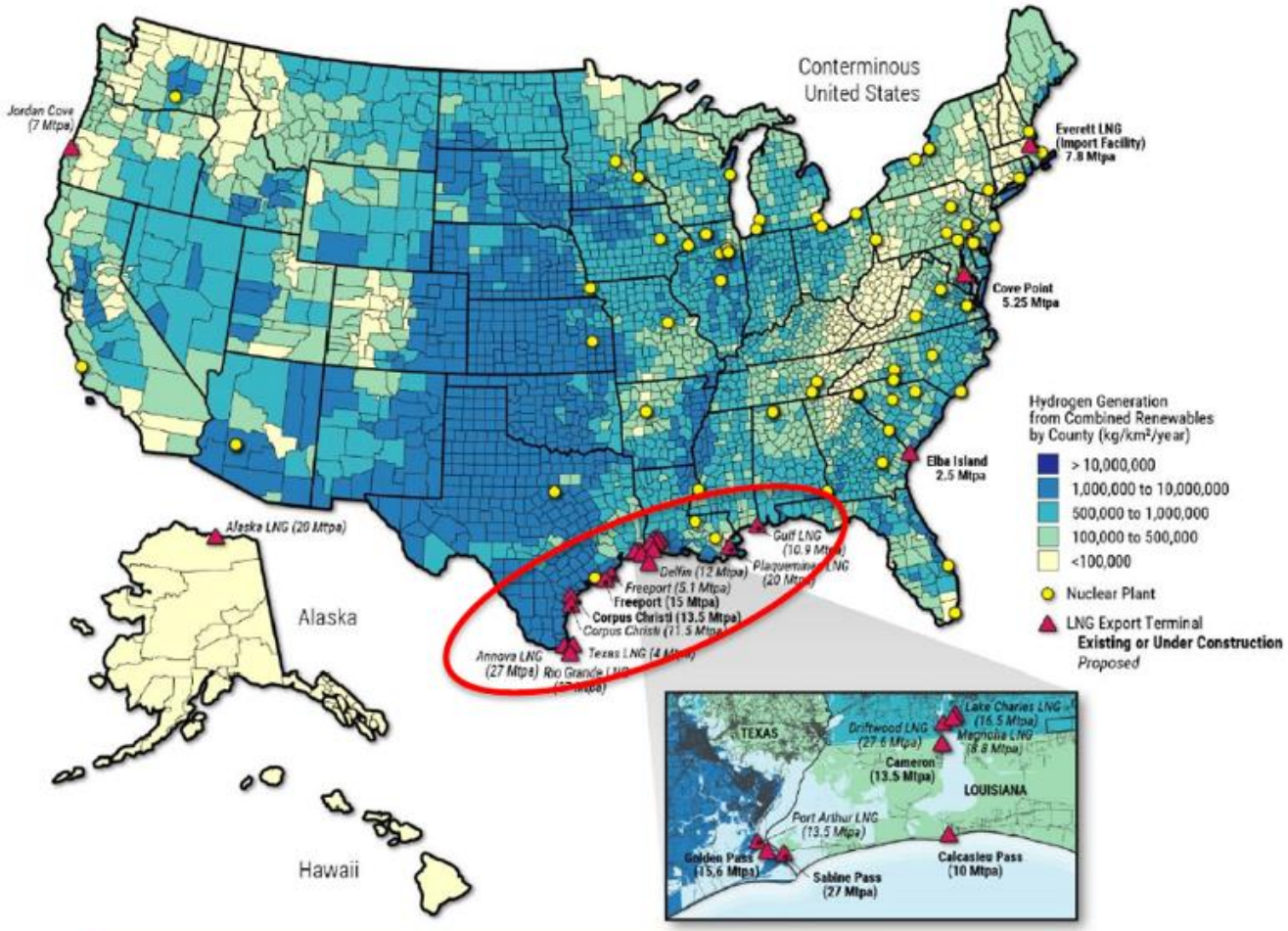
$$4H_2 + CO_2 \xrightarrow{\text{Biocatalyst}} CH_4 + 2H_2O + \text{Heat}$$

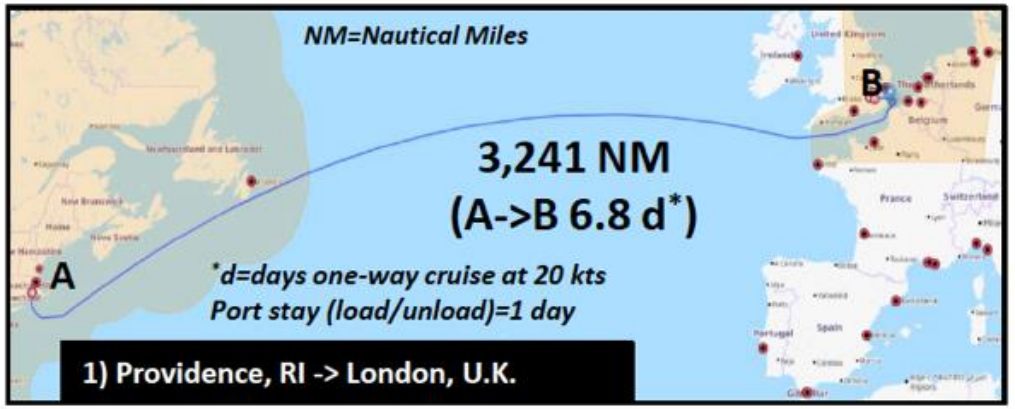


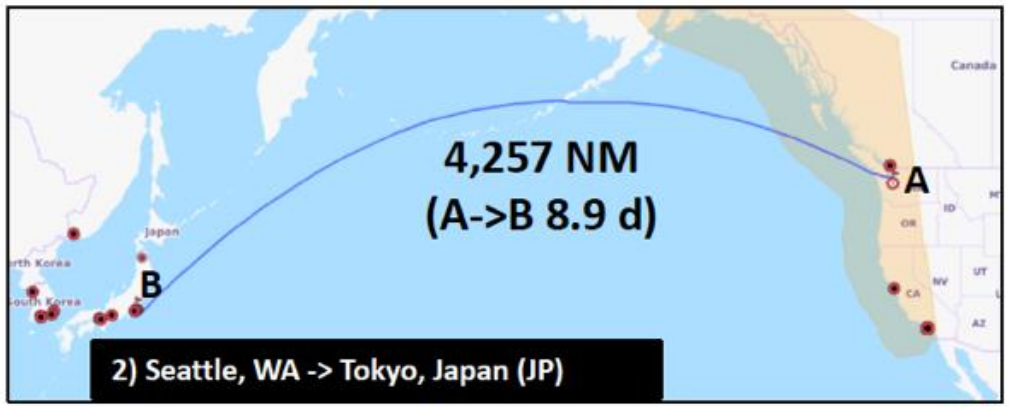




Potential for U.S. Hydrogen Exports: Analysis Underway







For more information, please see SA177 and ST001 presentations

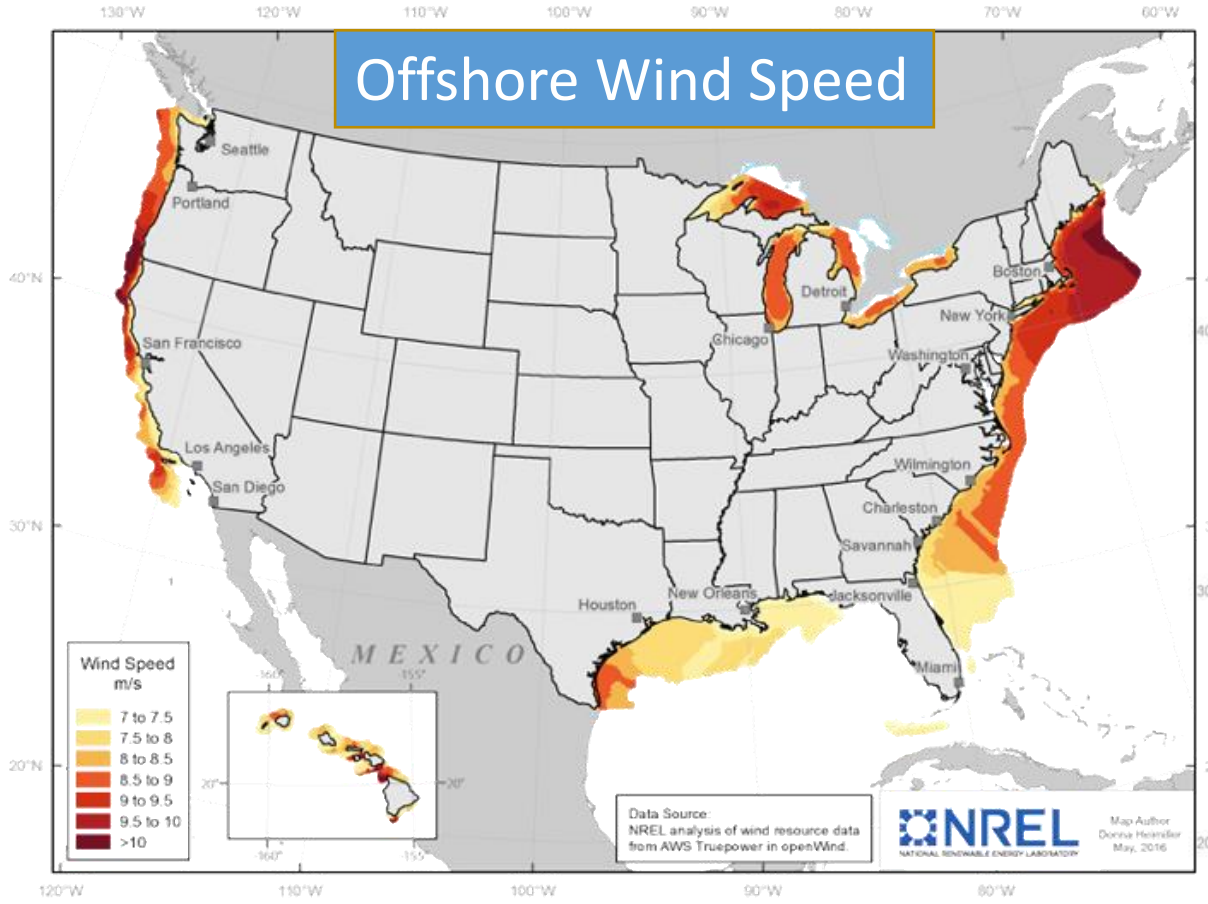
Preliminary

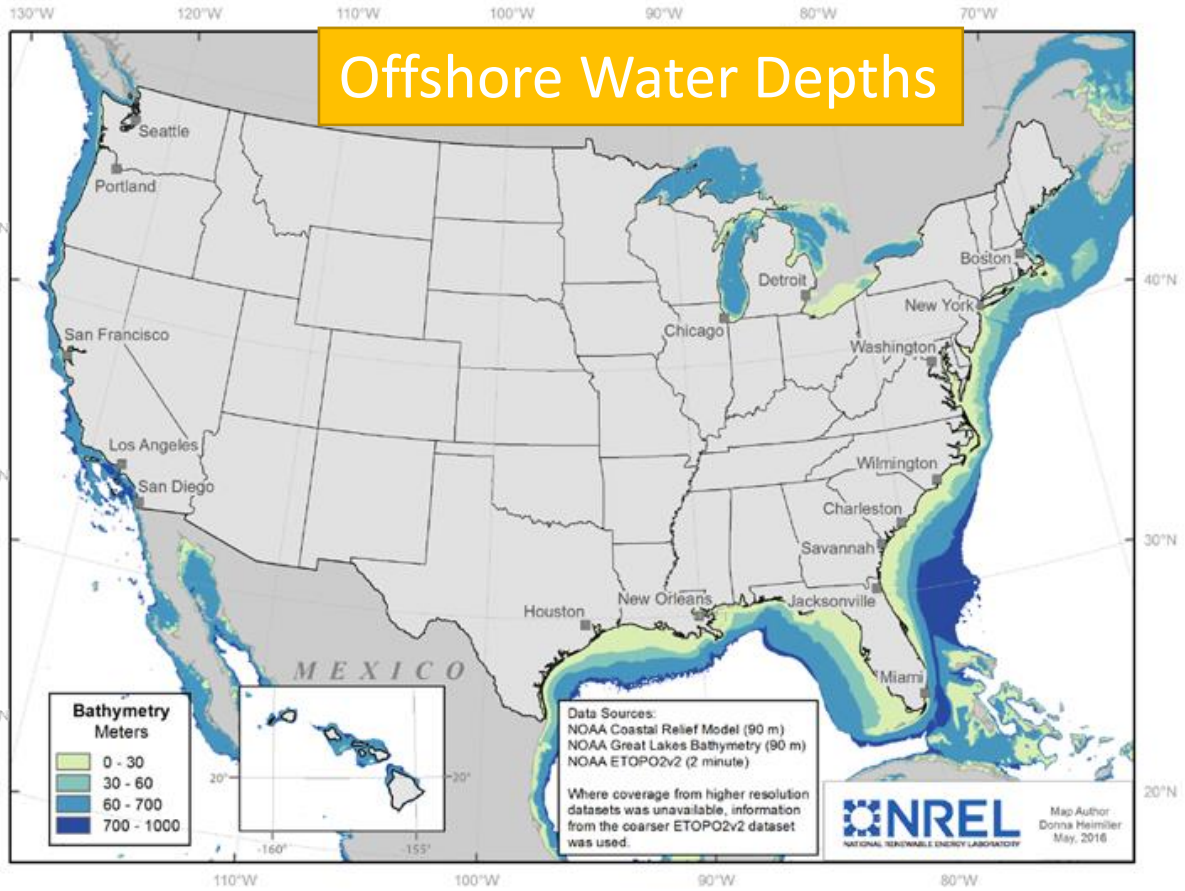
US LNG Export terminals are concentrated in the Gulf Coast near substantial resources for renewable hydrogen supply

Preliminary estimates of the cost of hydrogen export via liquid tanker from the U.S. to Europe or Japan: ~$5-$6/kg

Offshore Wind and Water Depth Resources

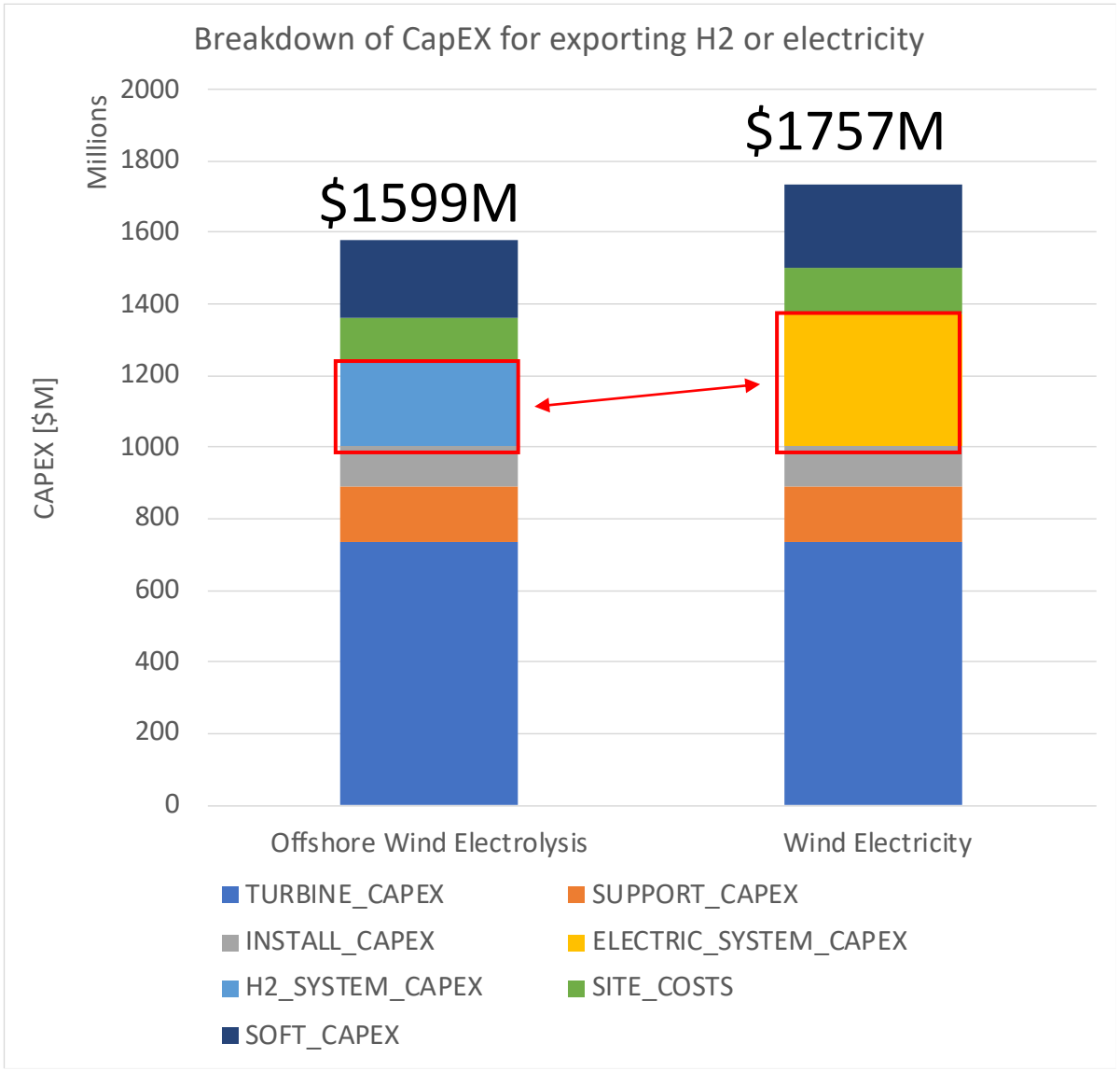
- Why offshore wind?
  - Significant resources that are also near population centers





Philipp Beiter, Walter Musial, Aaron Smith, Levi Kilcher, Rick Damiani, Michael Maness, Senu Sirnivas, Tyler Stehly, Vahan Gevorgian, Meghan Mooney, George Scott. 2016. *A Spatial-Economic Cost-Reduction Pathway Analysis for U.S. Offshore Wind Energy Development from 2015-2030*. NREL/TP-6A20-66579. https://www.nrel.gov/docs/fy16osti/66579.pdf.

Integrated Offshore Wind-electrolysis Analysis



$2.17/kg H2 at shore for site near Boston!

- H2 infrastructure replaces more expensive electrical infrastructure
- Electrical losses reduced

Hot off the Press: CRADA Call Released Today at AMR – June 7, 2021

Total Funding: up to $12M over 3 years*

- $500k - $2M per project, dependent on topic area
- Up to 14 projects total
- 30% cost share including 10% cash in
- National Lab leads w/ partners from industry, state & local govt, universities, and more

Topics

1) Integrated Hydrogen Energy System Testing & Validation
2) Applied Risk Assessment and Modeling for H2@Scale Applications
3) Next-Generation Sensor Technologies

Proposals due July 19, 2021

CRADAs are Cooperative Research And Development Agreements

*Pending Appropriations

www.nrel.gov/hydrogen/h2-at-scale-crada-call.html

Thank You

www.nrel.gov

Genevieve.Saur@nrel.gov

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NJ Green Hydrogen Forum

Panel 2: Green Hydrogen Production and Distribution

Moderator: Barry Carr, NJCCC

Speakers: Doug Copeland, Atlantic Shores Offshore Wind

Kyle Nolan, South Jersey Industries

Roy Bant, Chart Industries

NJFCC
NEW JERSEY FUEL CELL
COALITION

Atlantic Shores Offshore Wind

Hydrogen Pilot Project

PARENT COMPANIES

50/50 JOINT VENTURE

EDF Renewables

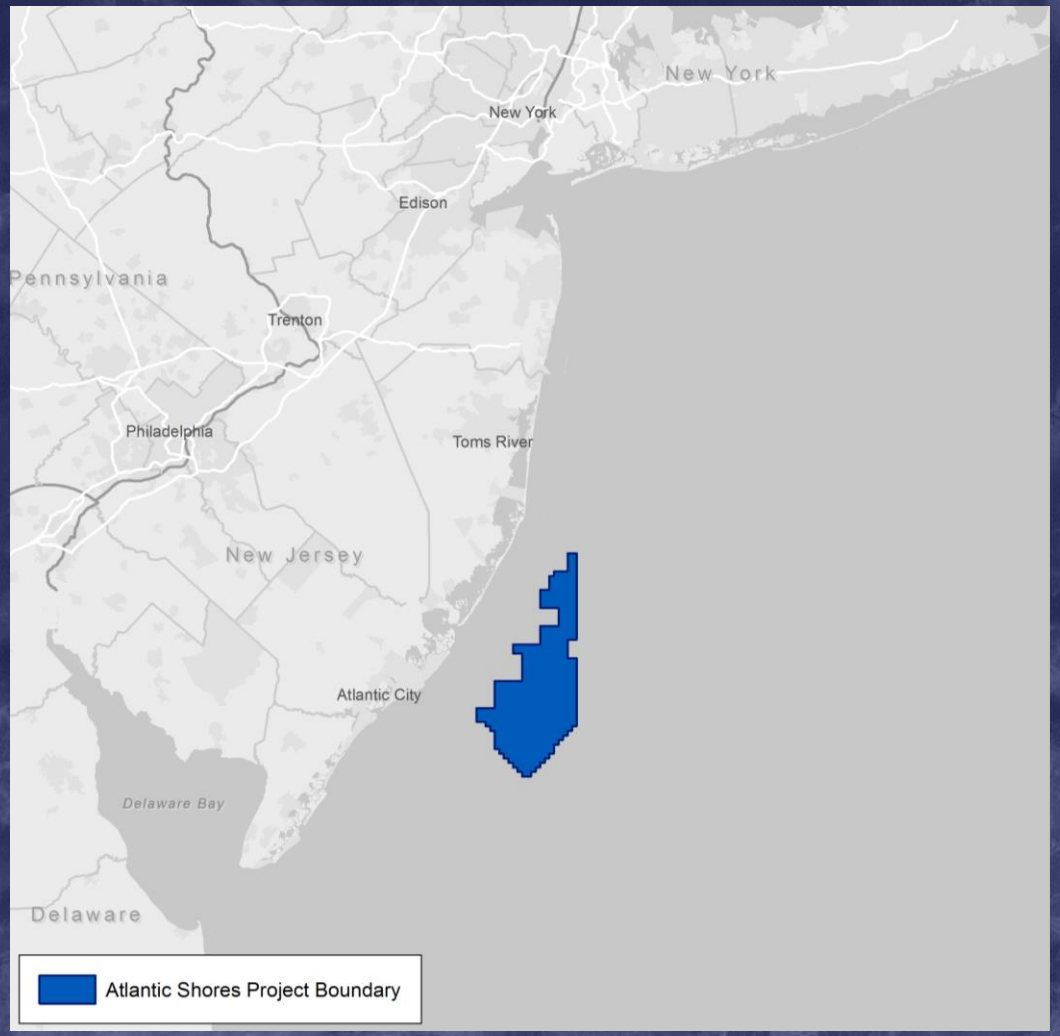
- Over **30** years' experience developing renewable energy assets in the US
- Actively developing and/or operating offshore wind project in **France, Belgium, UK & Germany**
- EDF Renewables alone has completed over 100 solar projects in **New Jersey**

Shell New Energies

- **40+** years of oil and gas operations in the US offshore
- **15+** years in wind
- Actively developing and/or operating offshore wind projects in the **Netherlands and US**

ATLANTIC SHORES offshore wind

Federal Lease Area



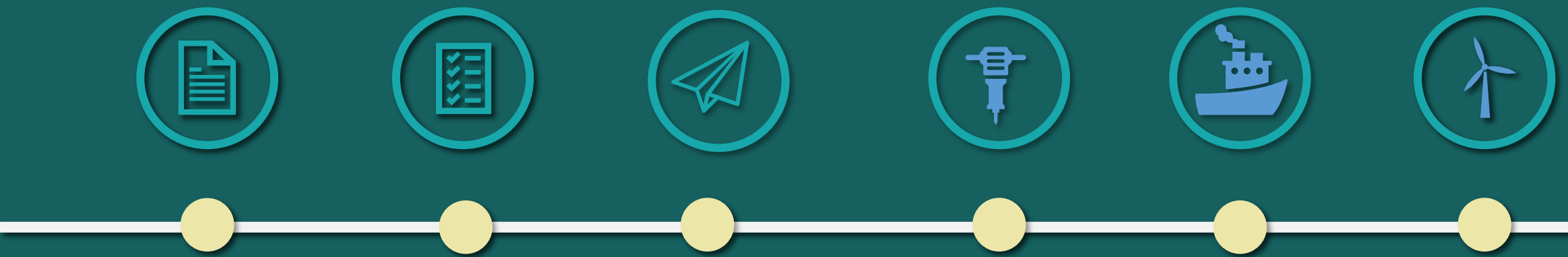
BOEM Lease Area OCS-A 0499

- Up to 3.0 GW of offshore wind projects
- 183,000 acres
- Approximately 10-20 miles off the coast of New Jersey
- 60-100’ water depth
- Expected to start delivering power in the mid-2020’s

Lease Area Designed to Support a Portfolio of Projects

ATLANTIC SHORES offshore wind

Atlantic Shores Development Schedule



Q4 2019
SAP Submission

Q1 2021
SAP Approval

Q1 2021
COP Submission

2024
Start of Onshore Construction

2025
Start of Offshore Construction

2027
Wind Farm in Operation

ATLANTIC SHORES offshore wind

Atlantic Shores Innovation Plan

2019 Energy Master Plan goal of reducing greenhouse gas (GHG) emissions by 80% by 2050 from a 2006 baseline.

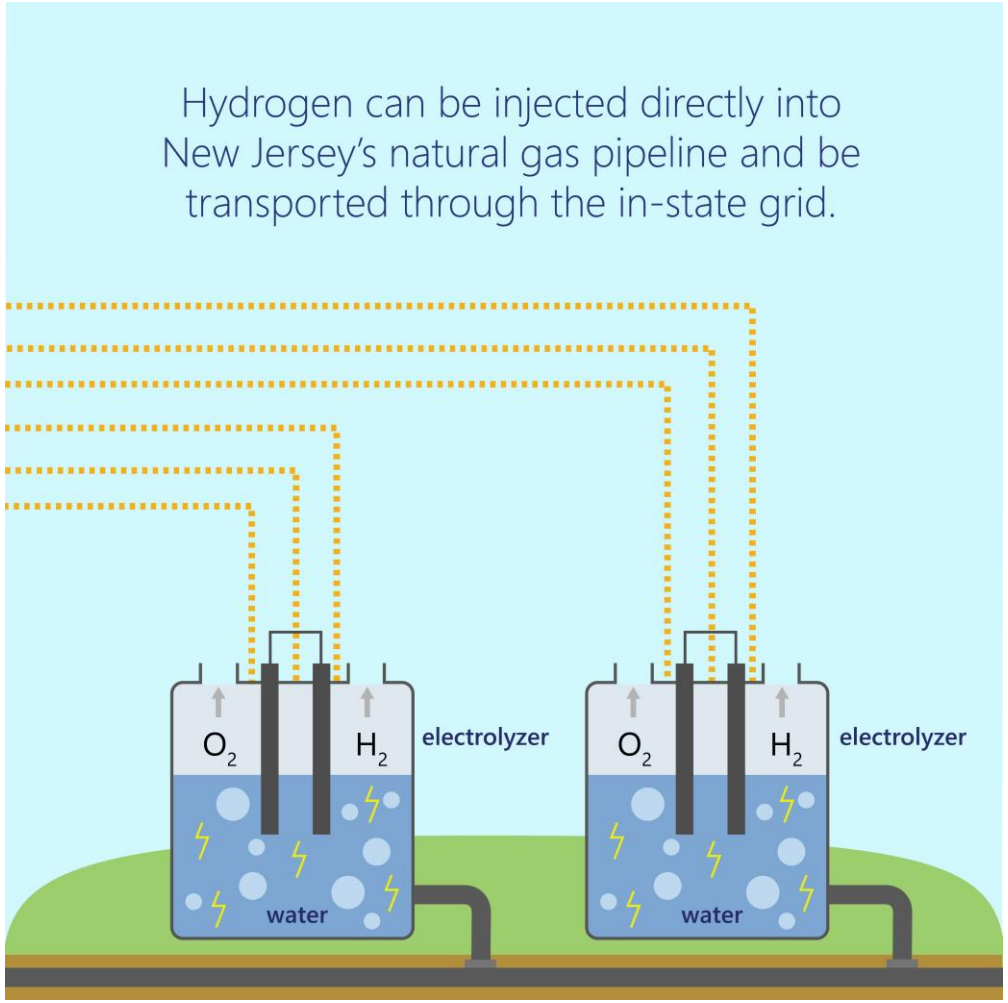
Target of **100% clean energy by 2050**.

Innovative solutions are needed to meet these goals and Atlantic Shores is committed to executing an innovation plan

Upon being selected, Atlantic Shores is to develop a hydrogen demonstrator plant (up to 10MW pilot) to support the **increased use of hydrogen as a fuel source for NJ.**

Atlantic Shores will be leveraging the technical capabilities of both parent companies to develop a pilot project with South Jersey Industries (SJI).

The pilot project consists of an electrolyzer to produce green hydrogen for blending into natural gas; and possibly other use NJ cases



ATLANTIC SHORES offshore wind

Thank You

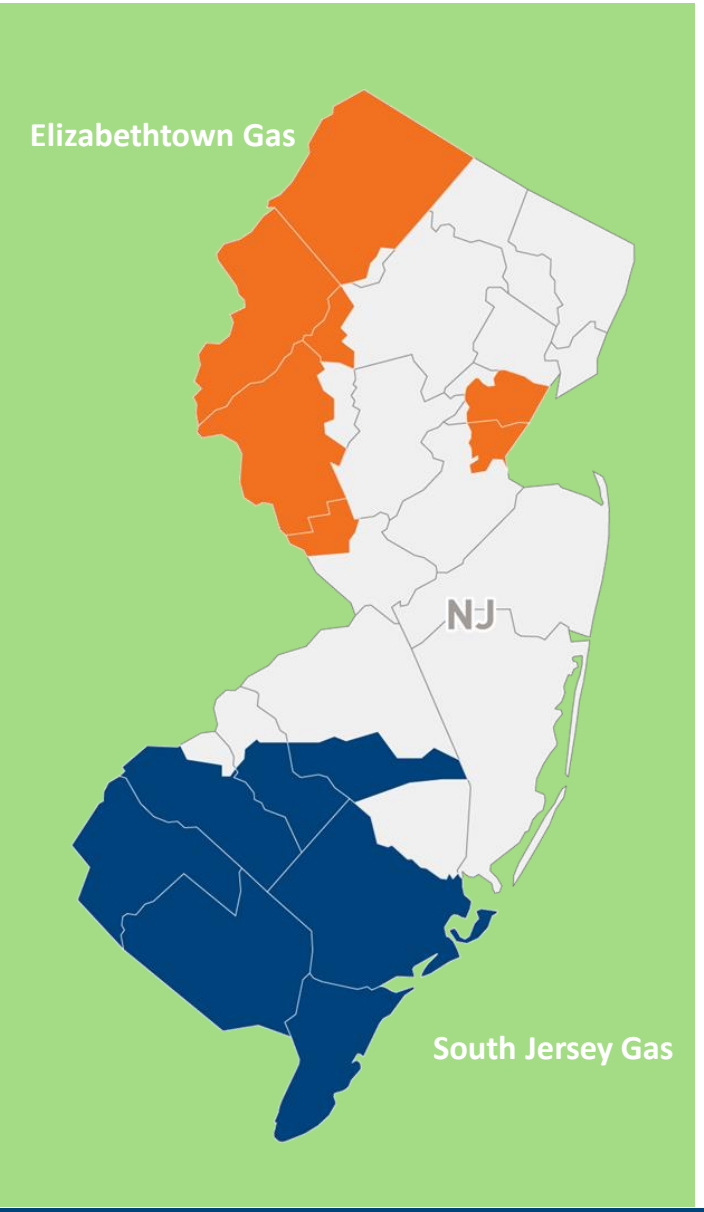
Questions?

Doug Copeland | Development Manager
Doug.Copeland@AtlanticShoresWind.com

Green Hydrogen Forum: SJI Perspective

Kyle Nolan / June 29, 2021

South Jersey Industries



Clean Energy Infrastructure Company across the energy value chain:

Utility:

-Elizabethtown Gas

-South Jersey Gas

Non-Utility:

-Energy Production

-Energy Management

Focusing on our Utilities (ETG & SJG):

-700,000+ Customers throughout the State of NJ

-Operate ~10,000 miles of distribution & transmission pipeline

-Recognized for Safety & Customer Experience

Why Green Hydrogen?

- Decarbonization
  - SJI has and continues to lower green house gas (GHG) emissions through infrastructure replacement programs, fleet conversion, energy efficiency programs, and more.
  - Infrastructure focus has laid the foundation to move towards alternative fuels which flow through the assets
  - Supporting NJ EMP and SJI's goals of achieving carbon neutrality
- Storage
  - Recognize the full value of renewable production and address the volatility of the production sources
  - Longer term storage opportunities as opposed to direct short-term opportunities (i.e. battery storage)
- Economic
  - Significant investments have been made to modernize our distribution system(s) & leveraging this existing infrastructure avoids the cost to ratepayer of building out unnecessary grid capacity

NJ Green Hydrogen Forum

Moving Hydrogen from Production to End-use

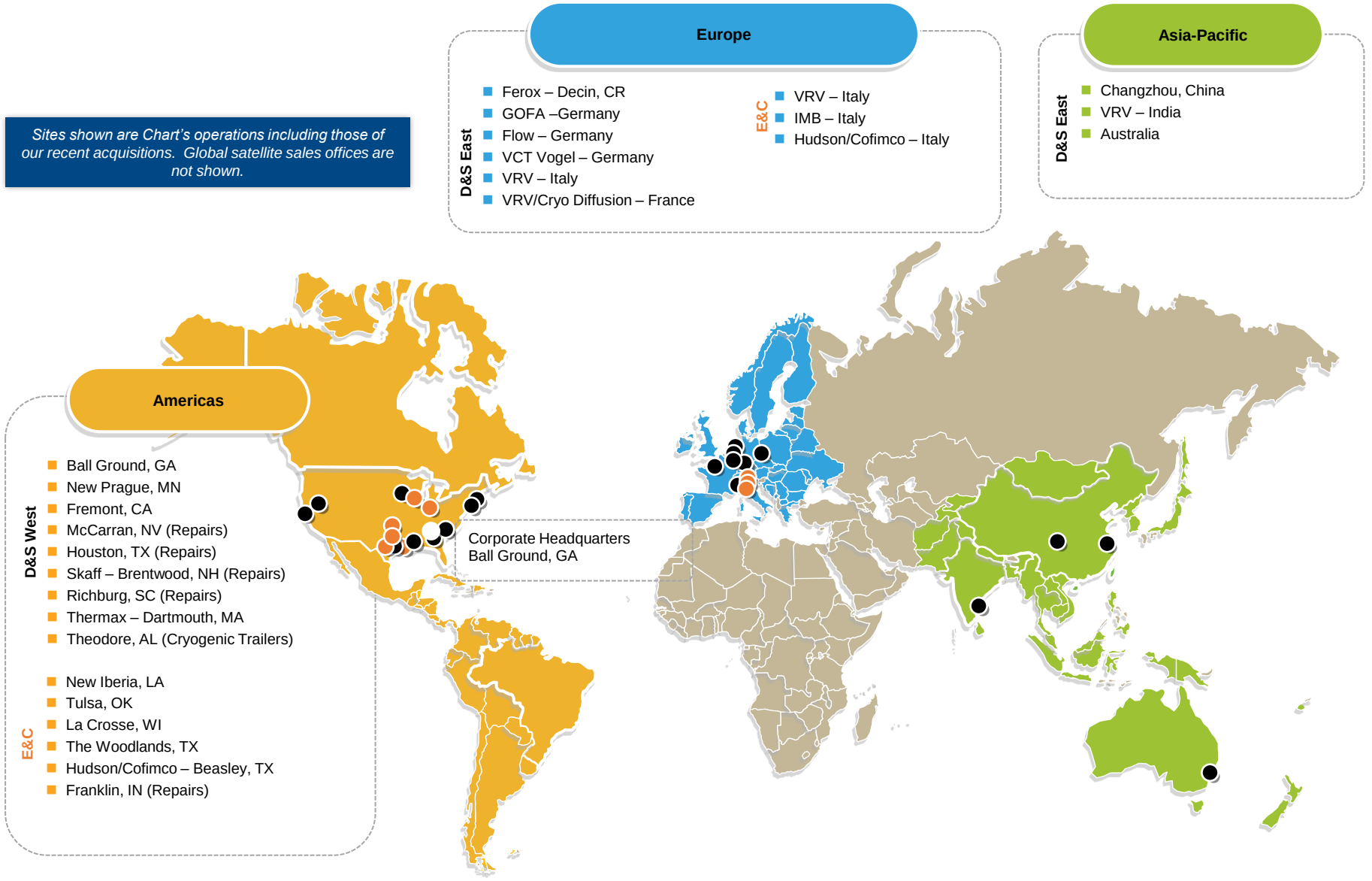
Roy Bant

Hydrogen Sales and Key Account Manager, Americas

CHART®

Cooler By Design.®

Sites shown are Chart's operations including those of our recent acquisitions. Global satellite sales offices are not shown.



Where We Play In the Hydrogen Supply Chain

CHART

McPhy

Electrolysis

Production

Gasification/ Reformation

Liquefaction

Cryo Technologies

Including Large Cryogenic Storage, BAHX, Load-Out Systems

Carbon Capture

Distribution

Worthington Industries

Liquid Transport Trailers, ISO Containers, Rail Cars, Marine transport

Storage

Cryogenic Liquid Tanks

End Use Systems

Electricity Generation

Vehicle Fuel Stations

Ammonia production (fertilizers)

Fueling Systems for Aerospace

Refining

Electronics Manufacturing

Marine Fuel

Key Components Integrated within Systems

Pumps and Compressors
Flowmeters
Vacuum Insulated Piping
Valves and Sealing

BALLARD

HTEC Hydrogen Technology & Energy Corporation

FIRSTELEMENT FUEL

PLUG POWER

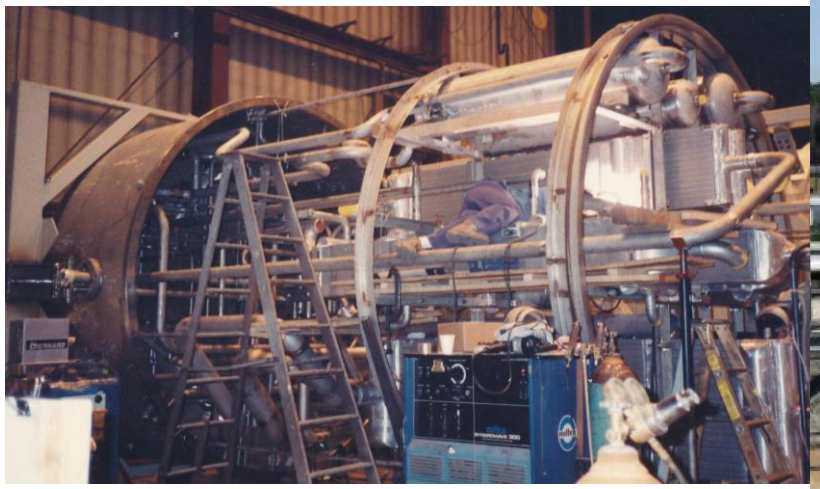
Partners and Users of Hydrogen

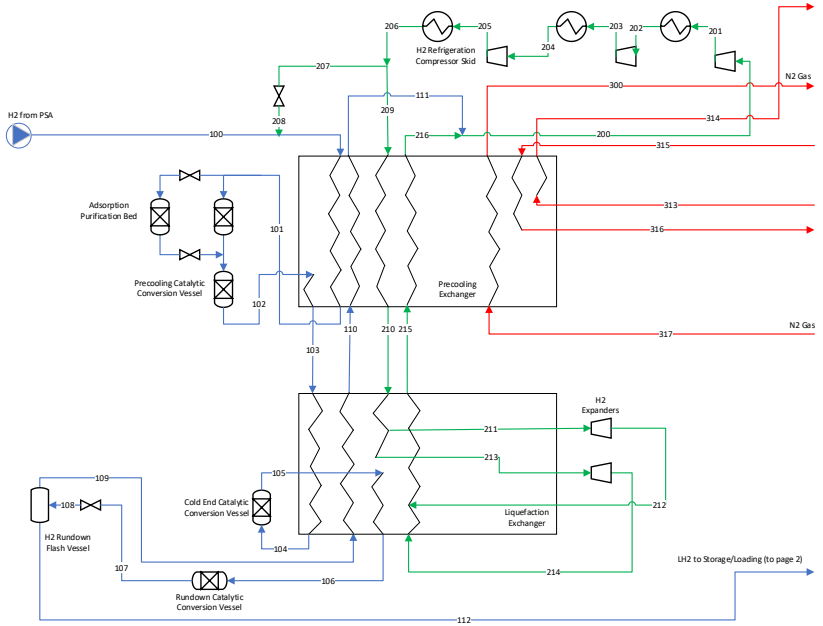
ULA America's Ride to Space

BLUE ORIGIN

Hydrogen Liquefaction

- Brazed Aluminum Heat Exchangers (BAHX) and Cold Boxes, Compressors and Turboexpanders are primary components
- Decades of experience in hydrogen liquefaction in industry
- Hydrogen liquefaction process options
  - Hydrogen or helium cooling
  - Precooling – sacrificial N2, closed loop N2 or mixed refrigerant





68

Liquid Hydrogen Storage

- Liquid Hydrogen is stored in vacuum-insulated stainless steel pressure vessels
  - Super Insulation
  - Materials and quality of construction is critical
- Hundreds/Thousands of tanks built for LH2
  - >800 LH2 bulk tanks built by Chart
- Storage tanks of all sizes available – 3,000 to 175,000 gallons shop-built, 1+ million gallons site-built

Liquid Hydrogen – Other Future Transport Options

- Rail Cars
  - Approximately 30,000 gallons / 8 ton storage
  - Regulations and standards on rail
- Marine vessels
  - Barges or custom vessels with integrated storage
  - Various sizes
- ISO Containers
  - Multimodal transport for road, rail, and marine
  - Approximately 11,000 gallons / 3 ton storage

Next Steps, Gaps in the hydrogen space, Questions?

- NJ to continue to lead Hydrogen efforts- NJ has been a leader w/ great support from key politicians that have helped with other States (Big Thank you to Chuck and Joanne)
- Leverage the current MOU signed by nine governors, including Governor Murphy for hydrogen vehicles and hydrogen infrastructure
- Gaps-address push back from environmental groups with their lack of understanding about how renewable hydrogen is made (not from refineries)- they continue to favor battery electric
    - Hydrogen from stinky refineries is not utilized for transportation-mostly used to produce fossil fuels
- Utilize key hydrogen stakeholders (Plug Power, Chart Industries, Air Liquide, Toyota, Nikola, Hyzon, Hyundai, Honda, New Flyer, DOE, etc)
- Lobby for railroad transportation of liquid hydrogen
- Lobby for more available, lower cost renewable electric power to produce green hydrogen

NJ Green Hydrogen Forum

Panel 3: Green Hydrogen Use in New Jersey and Beyond

Moderator: Brian Keelen, Air & Gas Technologies, NJCCC

Speakers: Charlie Myers, MA Hydrogen Coalition

Bill Zobel, California Hydrogen Business Council

Mike Strizki, NJ Hydrogen House Project

NJFCC
NEW JERSEY FUEL CELL
COALITION

Massachusetts Hydrogen Coalition

New Jersey Heavy Duty Truck Hydrogen Fuel Cell Program

Charles Myers
Massachusetts Hydrogen Coalition

June 29, 2021

Impacts of the New Jersey 2050 ZE MD/HD Goal

Complete adoption of zero emissions medium-duty and heavy-duty vehicles by 2050 estimated annual impacts:

- 636 avoided deaths from cardiovascular and respiratory illness.
- Work absences avoided
- $ million in total health benefit savings
- New jobs related to support of the vehicles and infrastructure

Source: Environmental Research Letter

Features a Zero Emission HD Truck Should Have

- Zero emission operation
- Driving range typical of current diesel technology
- Refueling experience and time comparable to that of today's diesel fueling
- Scalable infrastructure – sized to fit the need of the area, county and region
- No payload sacrifice for range or ZE benefit

Port & Truck Hydrogen Fuel Cell Equipment Options

Container Handling Equipment

Container Handlers

RTG (Rubber Tired Gantry Cranes)

Reach Stackers

Yard Dogs

Capacity

Toyota

Truck Hydrogen Fueling Infrastructure

Shell (CA)

Air Liquide (CA)

Nikola (AZ)

MD & HD Trucks

Toyota / Kenworth

Hyzon

Nikola

Hyundai Xcient

Hydrogen Fuel Cell Trucks Can Help EJ Communities

Distribution Center Examples That Have Existing Hydrogen Infrastructure On-site

Perth Amboy, NJ

Emission Reduction Annual (lbs)
5310
28840
107185
2437
2645

Cranbury, NJ

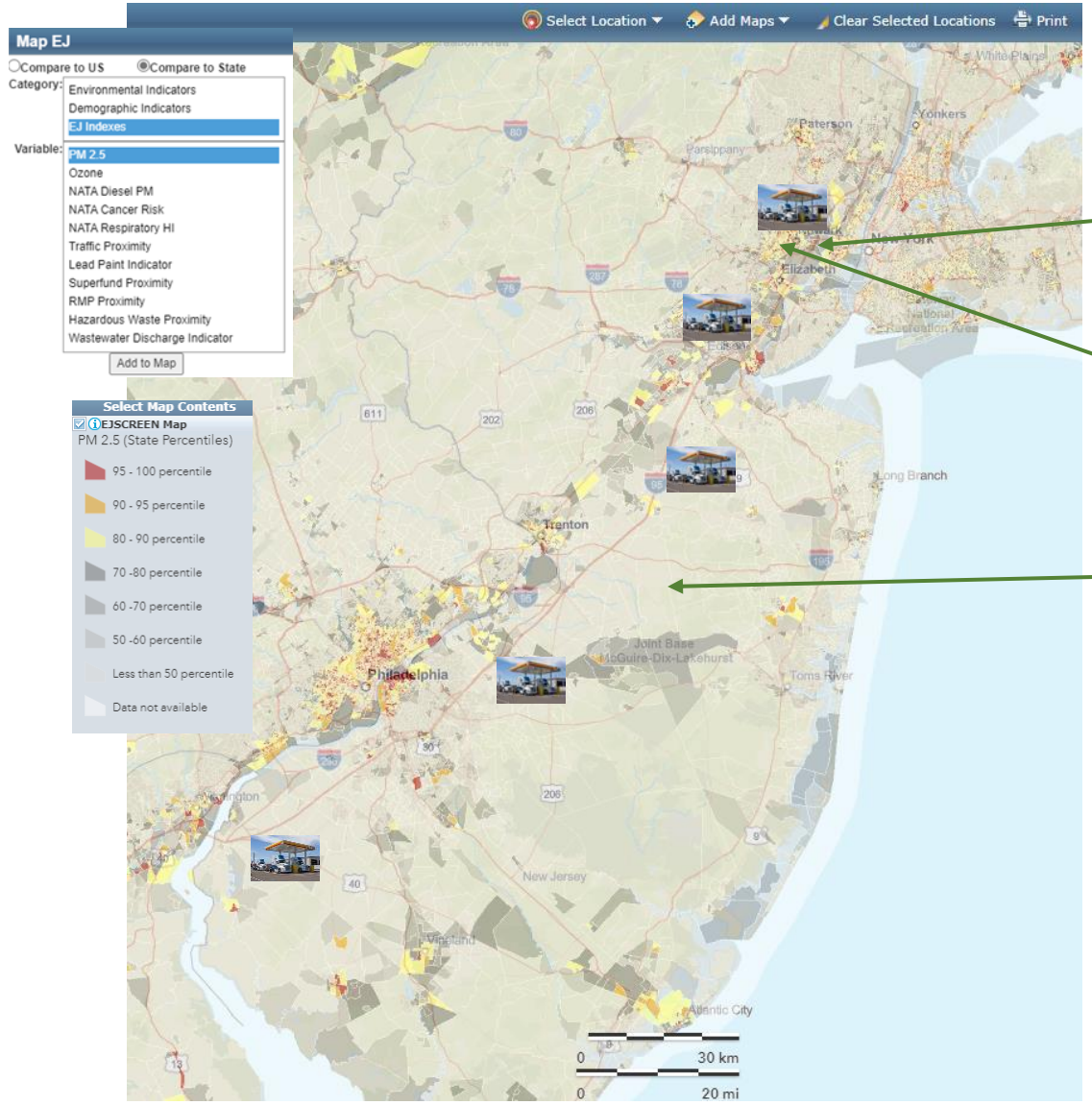
Emission Reduction Annual (lbs)
14964
81276
302068
6867
7453

Logan Township, NJ

Emission Reduction Annual (lbs)
19002
103212
383594
8720
9464

Example of on-site hydrogen infrastructure

New Jersey



HD Hydrogen Station

Freight Infrastructure

Ports of Newark & Elizabeth

22,896 kg/H2/day

Newark Int'l Airport (GSE)

5,163 kg/H2/day

Heavy Duty Truck

275,626 kg/H2/day

Cluster Daily H2 Demand
303,685 kg H2 / Day

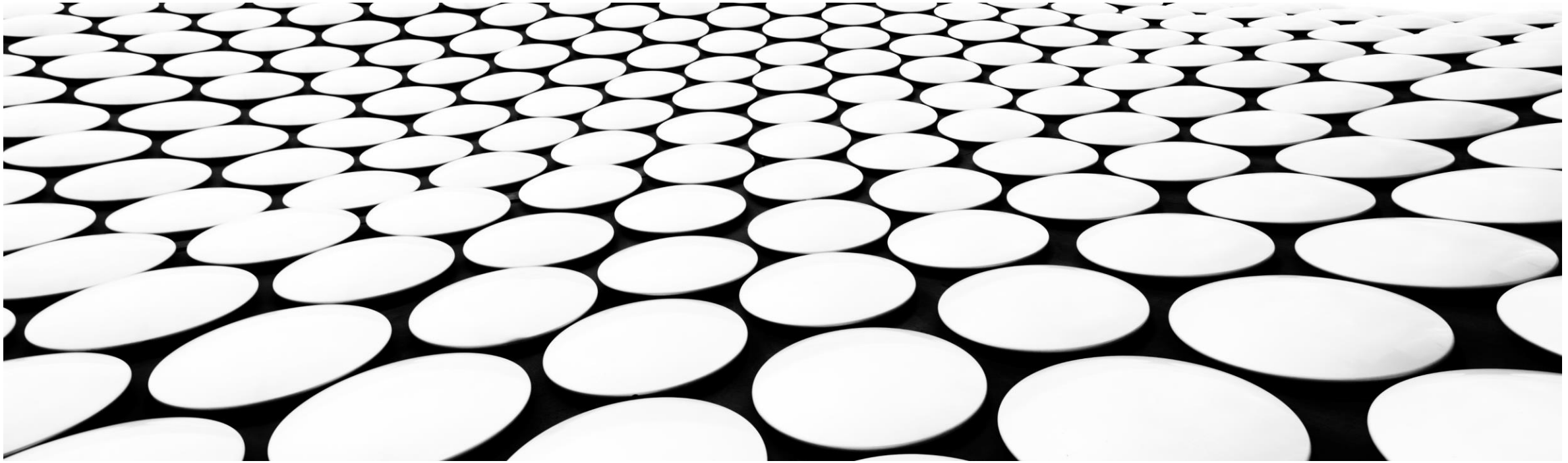
Annual Emission Reduction (tons)
391
2125
7897
180
195

Thank You

Charlie Myers
(508) 380-1759
cmyers@massh2.org

New Jersey Green Hydrogen Forum California Perspective

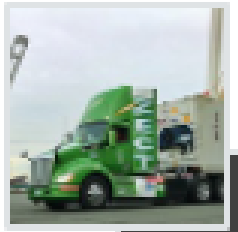
July 29, 2021



THE CALIFORNIA HYDROGEN BUSINESS COUNCIL

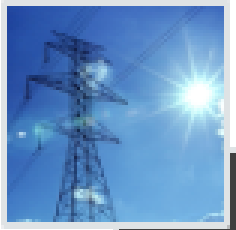
- OVER 120 MEMBERS
- RANGING FROM GLOBAL LEADERS TO START-UPS

CHBC ENGAGEMENT ON CALIFORNIA POLICY



TRANSPORTATION

- Vehicle and Infrastructure Incentives
- Cap and Trade
- Greenhouse Gas Reduction Fund (GGRF)
- Zero Emission Vehicle Regulations
- Low Carbon H2 Pathways for Transportation Fuel
- Optimizing the Low Carbon Fuel Standard (LCFS) for H2



GAS & ELECTRIC MARKET DESIGN

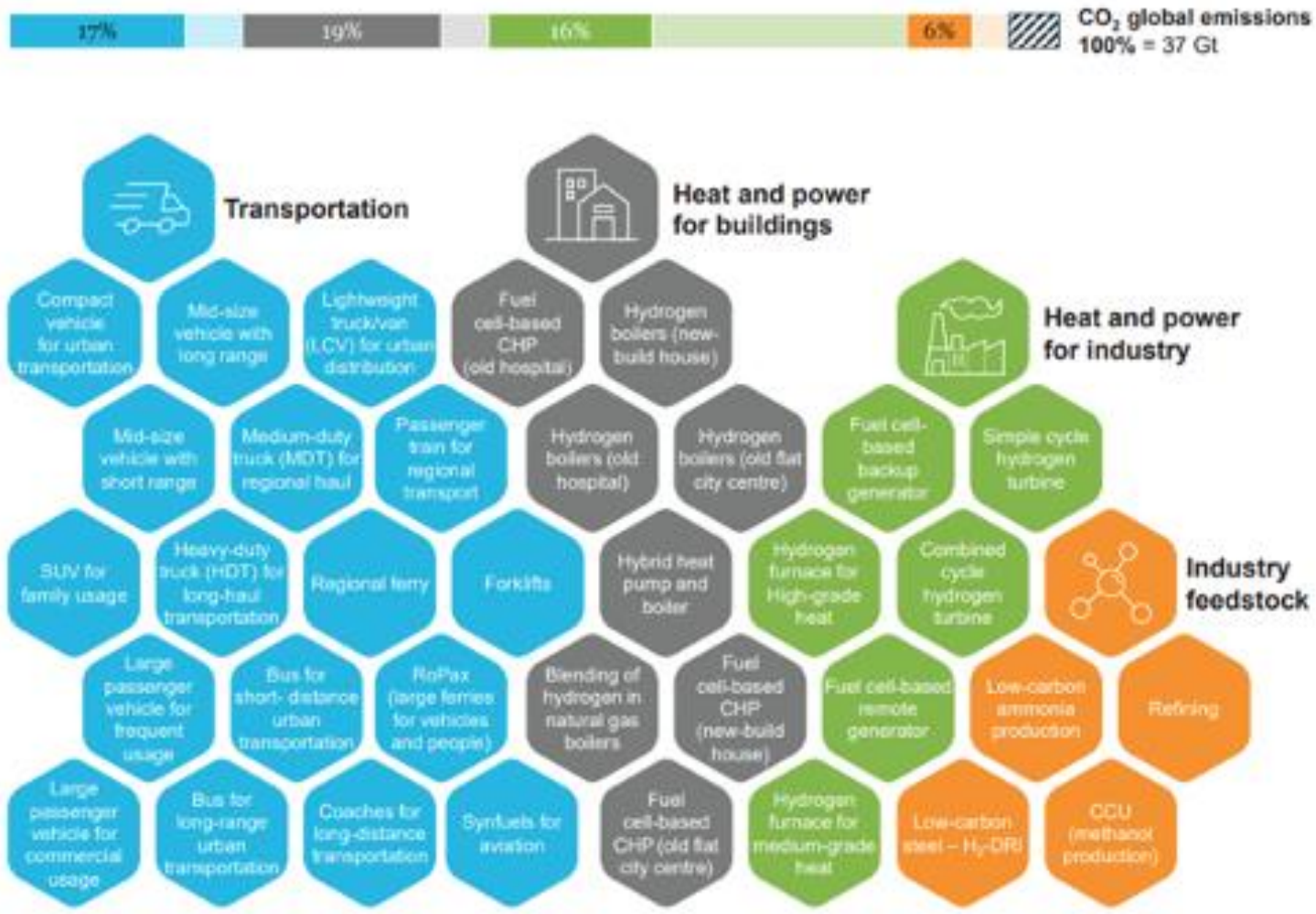
- Electric and Gas Grid Modelling
- Integration of Renewable H2 (RH2) into State Resource Planning
- RH2 Generation
- RH2 for Long-term Energy Storage
- Wholesale market access for RH2 production
- RH2 Pipeline Blending

DECARBONIZATION PLANNING

- Legislative Support for State Decarbonization Program Funding
- CEC Integrated Energy Policy Report
- Joint Agencies Low Carbon Power Plan (SB 100)
- CARB Scoping Plan for Point Sources, Vehicles and Infrastructure

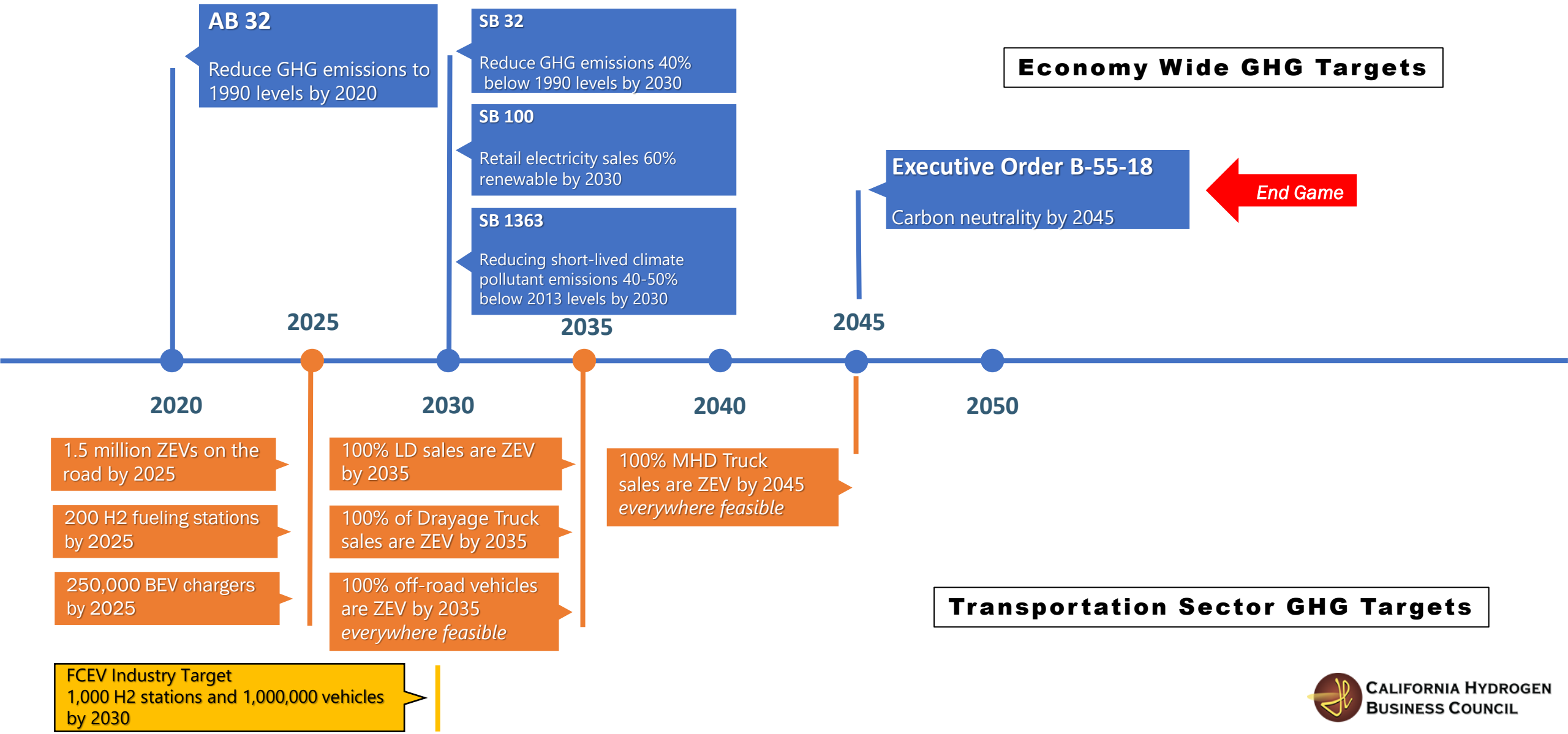
H2 IS A VERSATILE ENERGY CARRIER

- HYDROGEN CAN BE A VECTOR FOR DECARBONIZING SEVERAL MARKET SEGMENTS
  - TRANSPORTATION
  - HEAT AND POWER FOR INDUSTRY
  - HEAT AND POWER FOR BUILDINGS
  - INDUSTRIAL FEEDSTOCK



Source: Path to Hydrogen Competitiveness, The Hydrogen Council, January 2020

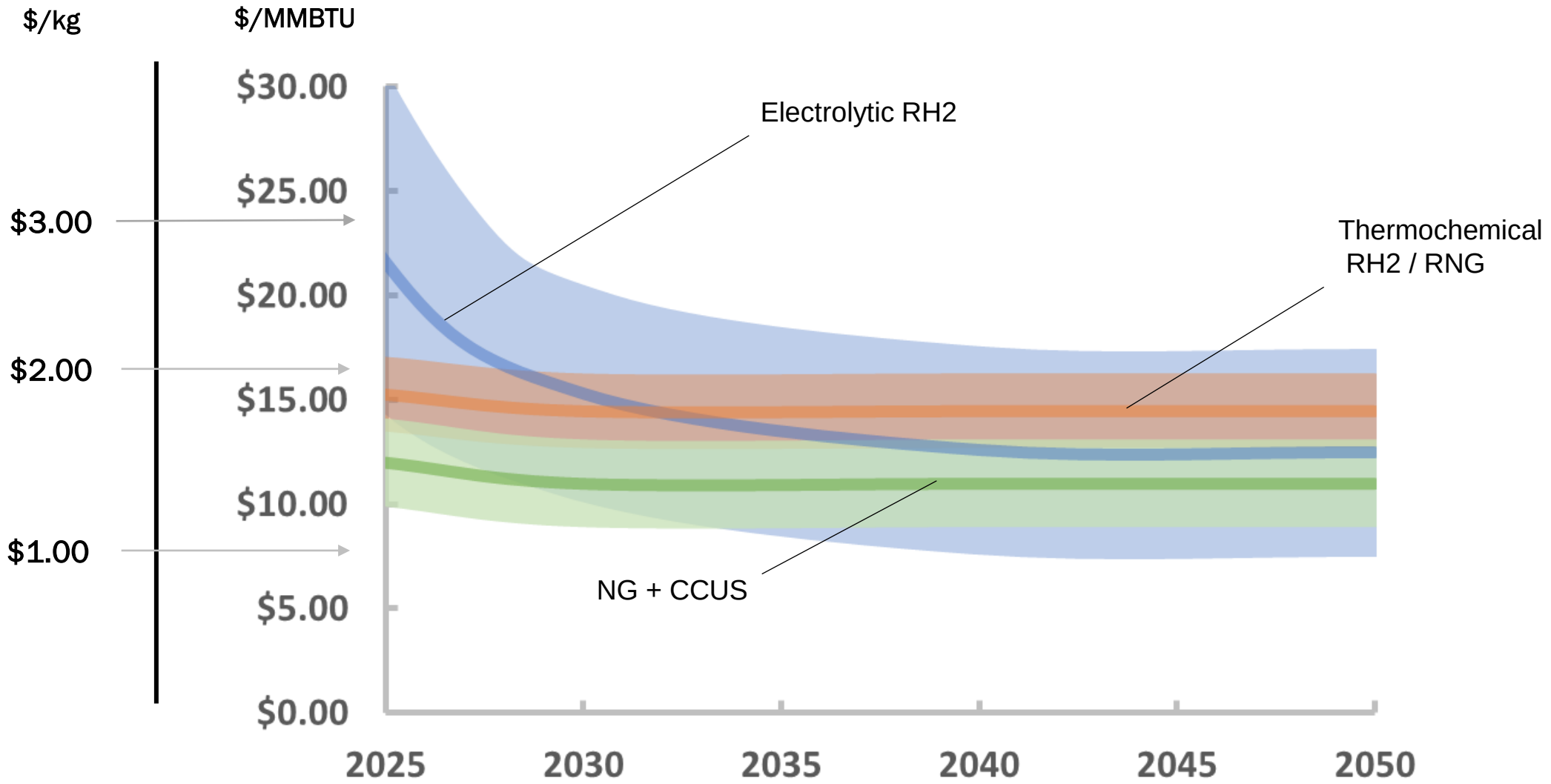
California GHG Goals



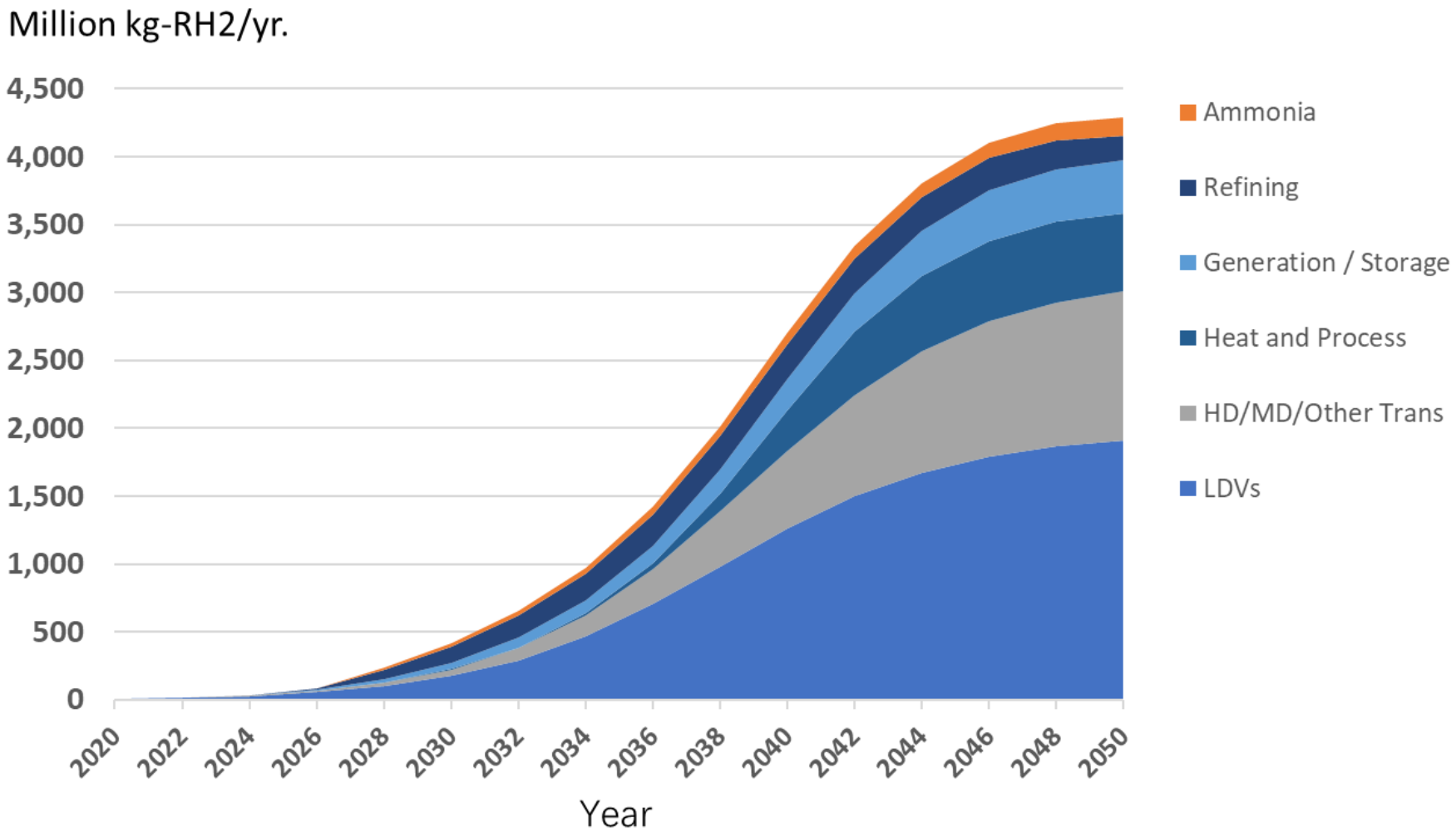
California Hydrogen Business Council

Hydrogen Means Business in California!

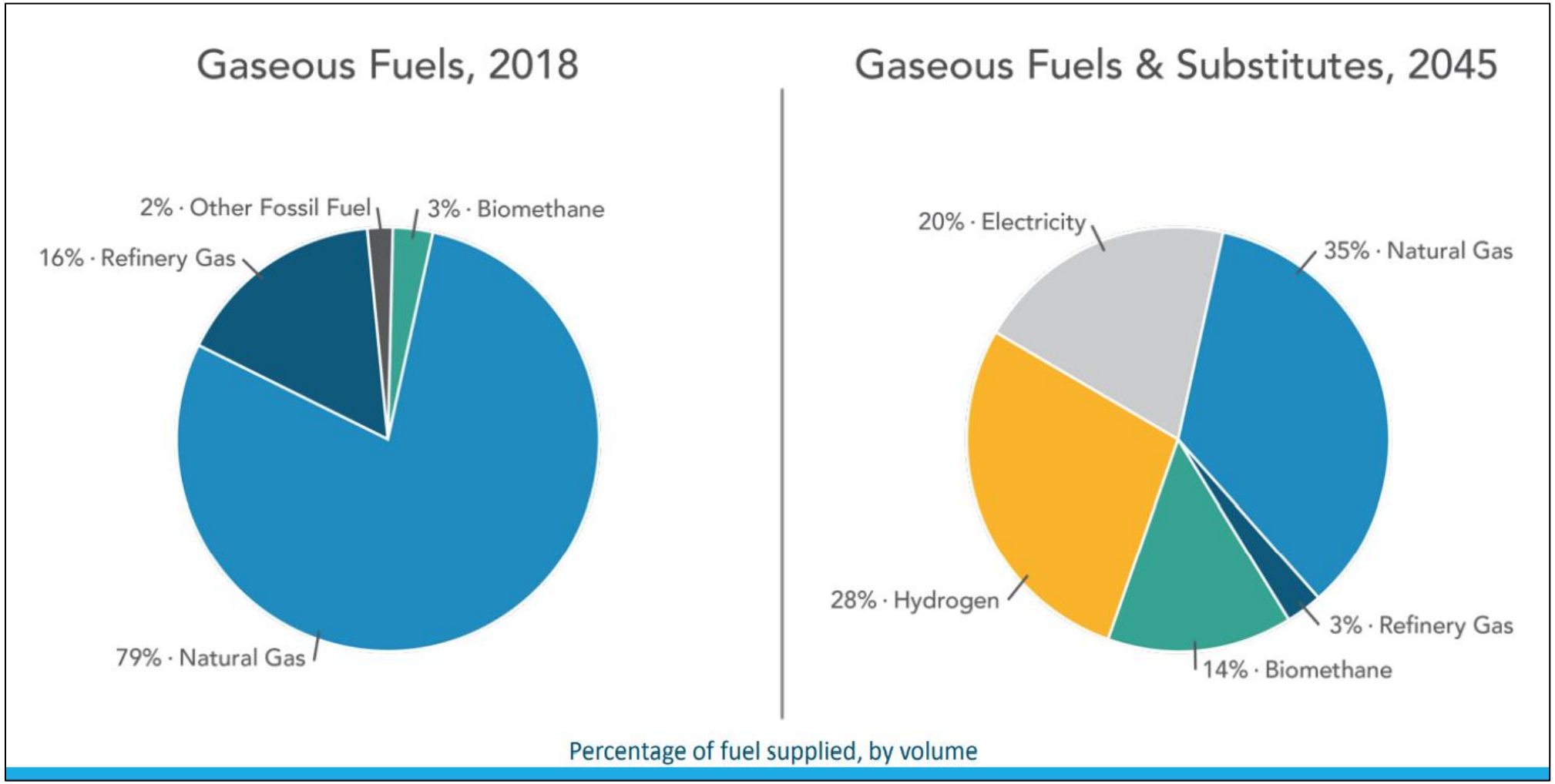
Multiple Pathways for Renewable / Green H2 available



High-Case California Renewable Hydrogen Demand to 2050



Gas Sector fuel mix projections



Source: CARB Board Update, November 2020

State policies to promote hydrogen development (excluding Transportation)

- State Level Strategy:
  - State Level Action Plan – Align Resources
  - Provide Investor Certainty
  - Fuel Neutral, Objective Approach (Carbon Intensity)
- Power Markets:
  - RH2 as an RPS Eligible Resource
  - Long Duration Energy Storage Requirements
  - Wholesale Market Access for Electrolytic Hydrogen
  - Resource Planning, Reliability Requirements, Grid Support
- Pipeline Distribution Markets:
  - Renewable Gas Blending (RGS) Standards / Requirements
  - Gas Utility Infrastructure Investments (i.e. common carrier systems)

Thank you!

William (Bill) Zobel
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wzobel@californiahydrogen.org
California Hydrogen Business Council – CHBC – Hydrogen Means Business in California

The Answer: Pathway to a Real World Hydrogen Economy Off-Grid and Micro-Grid Systems

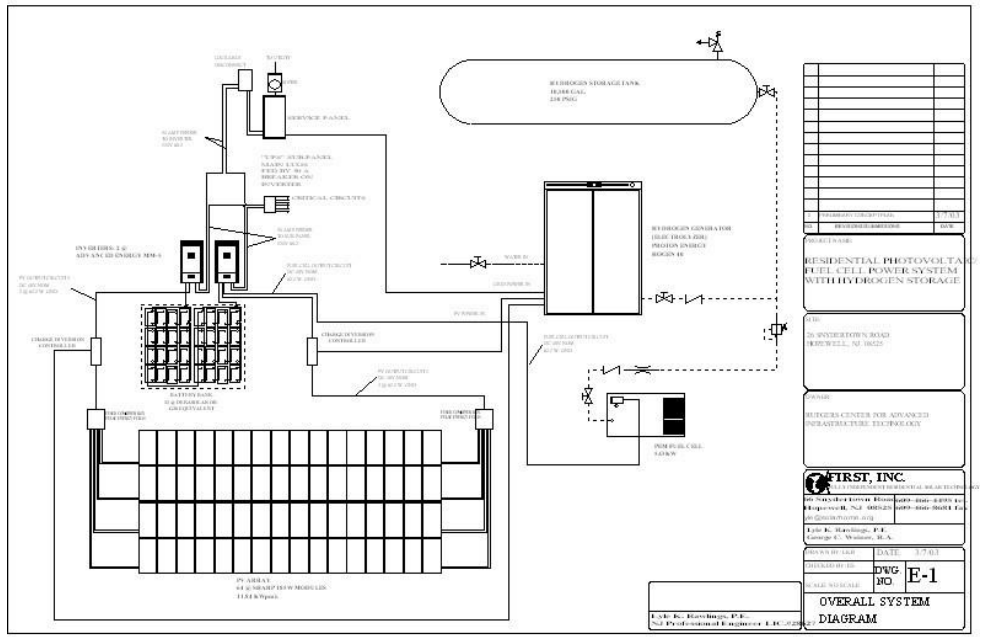
By MICHAEL STRIZKI
President
Renewable Energy Holdings
Hydrogen House Project

www.hydrogenhouseproject.org

REH

Hydrogen House

Solar Hydrogen Home System Layout

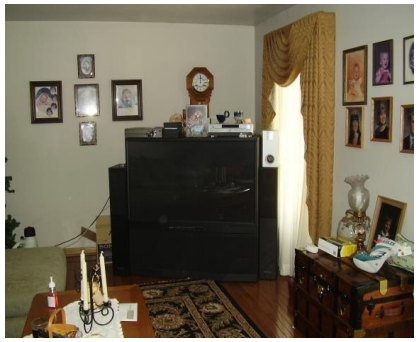


Solar Hydrogen Home Electrolyzer

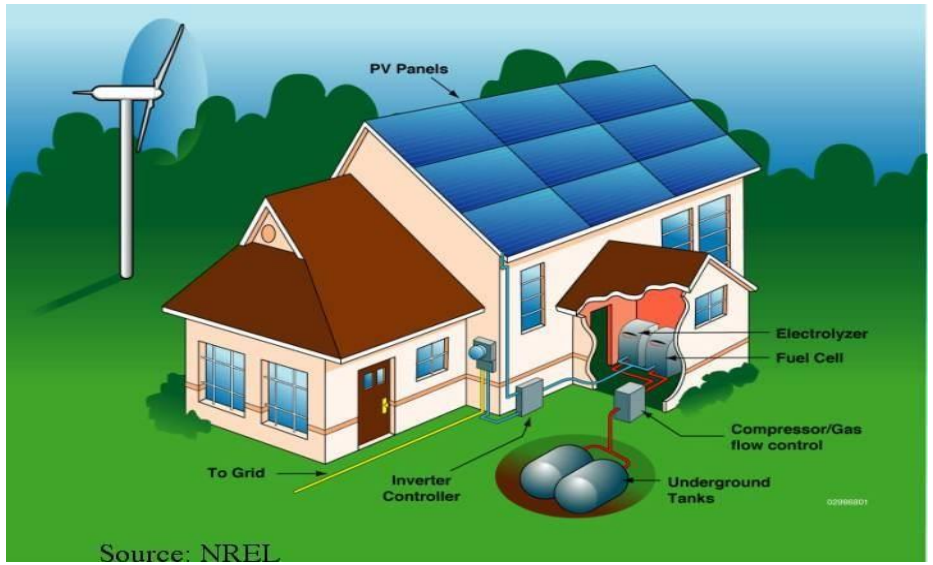
The electrolyzer is a HOGEN® 40 hydrogen generator with a maximum hydrogen production rate of 44scfh high purity hydrogen gas with a maximum delivery pressure of 200psig. The electrolyzer is capable of being powered by the utility grid and/or a DC renewable energy input source.

Grid Independent Solar Hydrogen Home Project



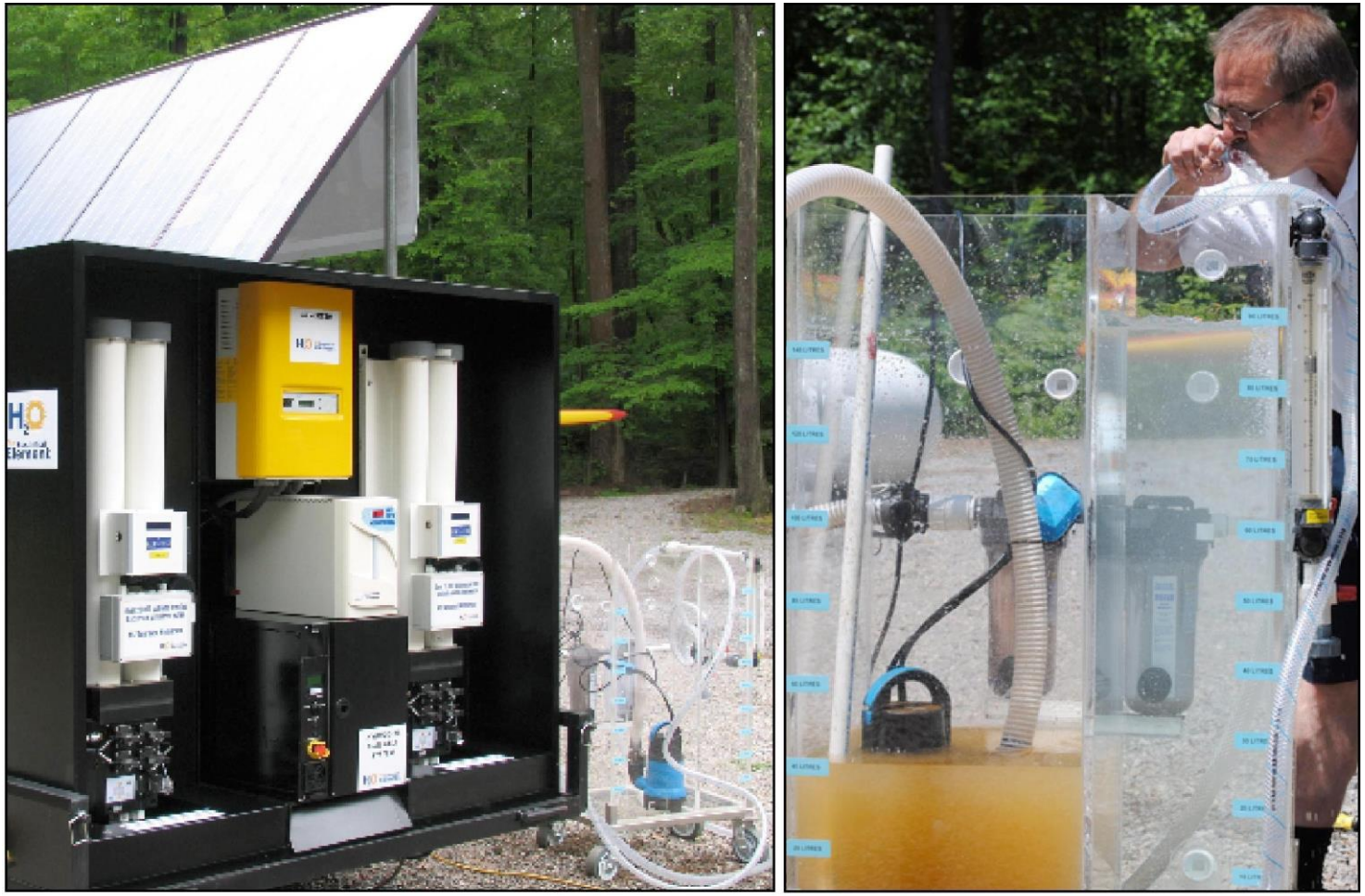



NREL Solar Hydrogen Home Vision



HYDRA H_2O

Solar Hydrogen Powered Portable Power and Water Purification Plant



HYDRA H2O purification plant produces the highest quality water while the hydrogen generator splits water into hydrogen & oxygen; Co-Inventor & CTO Mike Strizki takes a drink of HYDRA purified water

REH

Hydrogen House

Hydrogen Storage
Standard propane tanks 200psi
10,000 gallons

Hydrogen Heating

- Model #GFH6000
- Green Flame Heater
- Hydrogen fueled
- Save on heating costs. The 100% heating efficient designs requires no outside venting, so all the heat stays in the room.
- Humidifies dry air adding to the heating and comfort effect so you use less fuel.
- Provide Easy, economical installation, with no vent or chimney required, and a built-in pressure regulator, installation is an easy job*. (*Professional installation recommended)
- Safe and clean burning, Vent Free Gas Space Heaters are design certified by the American Gas Association and meet or exceed all government safety performance standards.
- A dual-purpose safety pilot system protects against oxygen depletion and any interruption in the fuel supply. If either event occurs, the gas is shut off to the burner, turning the heater off. (Note: Hydrogen will not make CO2 gas and never depletes oxygen in the room due to "Oxygen to water collapse vacuum factor"
- Provides heat during power outages. No electricity required, making them ideal as back up emergency heat.
- Clean, quite odorless operation
- Easy to use top mounted controls, push button ignition. No matches required.
- Decorative safety grill and tinted glass
- Low heat 4,400 BTU's (12 Gallons per hour H2)
- High heat 6,000 BTU's (17 Gallons per hour H2)
- Heater Dimensions 21.5" H x 13.5" W x 7" D

JOULE BOX

The Joule Box is a portable power unit which provides solar, wind, battery and hydrogen power.
It can be plugged into an 110v outlet, and can be configured to any size.

Product Advantages

- Provides immediate power in emergency situations
- Extremely small footprint compared to energy produced
- Expandable to fit most power requirements
- Non-permanent installation, can be moved or relocated
- Qualifies for Federal and State tax incentive programs
- Made in the USA

Power Specifications

- 1,440 watts of electric solar power
- 100 amp hours of battery power[1]
- 1,100 watts of hydrogen power[2]
- 1,000 watts of wind power[3]

Physical Dimensions

- 6' x 6' x 16' (including solar & wind attachments)
- 48" x 48" (actual footprint)

Component Specifications

- (4) 12v 100ah lead acid batteries (48v)
- (12) 120 watt solar modules
- (1) SMA 5,000w off-grid power inverter
- (1) ReliOn 1,100w hydrogen fuel cell
- (1) Proton P.E.M. hydrogen generator system (200psi)
- (1) Xantrex C40 charge controller
- (3) Maxwell 16v BMOD0500 ultra capacitor
- (4) 100lb 4K high pressure cylinders

1. 100 amp battery packs can be added for more battery power
2. Hydrogen power is limited to the amount of stored hydrogen available
3. Wind power is rated at a wind speed of 8mph

RENEWABLE ENERGY HOLDINGS
97 River Road Flemington, NJ 08822
Ph: (908) 788-7750 Fax: (908) 837-9021

Electrolyzer Technologies

Current Technology

- State of the Art Alkaline Electrolyzer, Efficiency: 60-70% (LHV)
- Operating temperature: up to 80°C
- Operating pressure: 1 atm – 25 atm
- Cost: ~$1000/kW - $2500/kW

Stuart Electrolyzer

Future Technology

- Increase capacity, efficiency and reduce cost
- System efficiency should reach 70-80% (LHV) by advanced
- electrolyzer technology
- Industrial size electrolyzer (MW level)
- Cost should be reduced to $300/kW - $500/kW (COH at $2/kg)
- Integration with renewables (wind, PV, geothermal, etc.)

Company	Energy Consumption (kWh/Nm3)	H2 Production (Nm3/hr)	Input Power Rating (kW)	Pressure (bar)	Efficiency (HHV)	Efficiency (LHV)
Norsk Hydro	4.1-4.3	up to 485	50 - 300	0.5 - 1	72-85%	61-72%
	4.8	up to 60		~ 15	83-86%	70-73%
Teledyne Energy Systems	5.3-6.1	up to 42	-	4-8	79-85%	67-72%
	5.6-6.4	up to 150		8-15	78-84%	66-71%
Stuart Energy	5.9	>50	-	1-25	80-83%	68-72%
VDBH (Stuart Energy)	4-4.2	10-60	60 - 360	~ 25	86-88%	73-75%

New Technology Development Required for Megawatt Scale Electrolyzer

Hydrogen From Biomass - Carbon Free

Waste to Energy

- Agriculture waste will play a major role in the upcoming Hydrogen Economy. Pictures illustrate the process in California used to convert carrot waste into fertilizer and hydrogen gas with no carbon footprint

Major Benefits

- Reclaiming agriculture waste once paid to dispose of
- Process takes only 2 days versus 21 days with anaerobic digestion and carbon release
- Process generates a 70% profit margin by reselling the waste as liquid and solid fertilizer and generating 12 kg/ton of hydrogen with no carbon release

Types of Hydrogen Generation from Organic

- Anaerobic digestion
- Steam reformation of landfill gas
- Conversion of other organic solids
- New processes being developed daily to extract hydrogen from nature

Closing Remarks

Implementation Plan

- Currently almost all major automotive companies and heavy machinery industries have invested in hydrogen technology and continue to do so to meet the current administration's goals for carbon reduction and circumvent the effects of global warming

- 94% of all greenhouse gases can be mitigated by advancing a worldwide hydrogen economy. Europe is already 6 years ahead of the United States in implementing these technologies

- ❖ All the technology currently exists to implement a hydrogen economy today
- ❖ Advances over the last 20 years have led us to this point where this can be done today
- ❖ The United States will miss out on the economical and environmental boom unless we educate our public and act now to implement a hydrogen economy
- ❖ I am recommending that we take action to implement incentive programs, like what we did with solar at a 70% incentive level for hydrogen re-fueling stations
- ❖ Implementation of an educational program to inform the public, schools, and government of the benefits of a hydrogen energy infrastructure and the training of the next generation of students
- ❖ We need to fund implementation projects **now** for us not to be at a disadvantage to the rest of the world when this wave hits

Hydrogen refueling Stations are desperately needed in New Jersey to complete the Hydrogen Highway northeast corridor. 5 stations located in New Jersey will cover the whole state. New Jersey is the most densely populated state in the Country bordered by the largest cities in the country. One station will be capable of doing 400 cars a day and can be done from renewables which are already located throughout the state. Other stations will be opening in the northeast this year, New Jersey should not be the last to follow suit. The time is now! The clock is half past midnight. Thank you for your time.

Mike Strizki
President
609-731-1990 (CELL)
Hydrogen House Project
www.hydrgoenhouseproject.org
Renewable Energy Intl.

Coming this Fall…

Decarbonizing Gas in New Jersey

An Educational Forum Focusing On:

Renewable Natural Gas and Green Hydrogen

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