New Jersey Clean Cities

ENERGY VISION

Agenda

2:00 pm **Welcome & Opening Remarks**
Chuck Feinberg - Executive Director, New Jersey Clean Cities Coalition & Partner, Greener by Design

2:05 pm **Perspectives on the New Jersey Master Plan**
Adam Zellner - Former Sr. Policy Advisor to the NJ Governor & President of Greener by Design

2:20 pm **Low Carbon Gases: Production, Uses & Benefits**
- Matt Tomich - Energy Vision
- JoAnn Milliken - New Jersey Fuel Cell Coalition
- Tucker Perkins - Propane Education Research Council
- Andrew Burnham - Argonne National Labs
- John Gonzales - National Renewable Energy Lab

3:10 pm **Advancing Low Carbon Gases Today: Industry Perspectives**
- Dan Hagan - Waste Management Organics
- Mark Kahrer - New Jersey Natural Gas

Panel Discussion

3:45 pm **Case Studies: Decarbonized Gas Now**
- Juan Corcino - Manhattan Beer
- Rick Dovey - Atlantic County Utility Authority
- Ricardo Hamdan - Hitachi Zosen Inova
- Chelsea Jenkins - Roush CleanTECH

4:25 pm **Wrap Up & Closing Comments**
Joanna Underwood

Decarbonizing Gas in New Jersey
An Educational Webinar

Chuck Feinberg
Executive Vice President, Greener by Design
Executive Director, NJ Clean Cities Coalition
November 4, 2021

Perspectives on the New Jersey Energy Master Plan

Adam Zellner

Former Sr. Policy Advisor to the NJ Governor
President of Greener by Design

Greener by Design

Low Carbon Gases: Production, Uses & Benefits

- Matt Tomich – Energy Vision
- JoAnn Milliken – NJ Fuel Cell Coalition
- Tucker Perkins – Propane Education Research Council
- Andrew Burnham – Argonne National Labs
- John Gonzales – National Renewable Energy Lab

Turning Organic “Waste” into a Valuable Resource:

Renewable Natural Gas (RNG)

A Climate & Clean Air Solution for NJ

Matt Tomich, President, Energy Vision

Decarbonizing Gas in NJ

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Biogas 101

- When organic wastes decompose in an oxygen-free environment, they release *biogas*. This process is called ***anaerobic digestion***.

- Biogas is typically 50% - 65% methane (depending on the source).

Landfills

Water Treatment Facilities

Dairy Farms

Complete mix digesters on a dairy farm in Florida

Trench digester on a dairy farm in New York

For processing food waste

VEOLIA CANADA

Toronto, Ontario

QUANTUM BIOPOWER

Quantum Biopower, CT

Historically, biogas has been used to produce electricity and/or heat

CHP system at landfill, Quebec

CHP system at Coney Island WRRF, NYC

Biogas can also be *upgraded* to **renewable natural gas (RNG)**

- 95+% methane
- “Pipeline quality”
- Flexible, multi-purpose

RNG is a versatile strategic energy resource that can readily displace fossil fuels in a variety of applications:

- Power Generation
- Industrial Uses
- Heating/Cooling/Cooking
- Transportation (both as a fuel and as a feedstock for other energy dense options, e.g. H2 or SAF)
  - ***Has much lower lifecycle emissions: 50% to 300+%***




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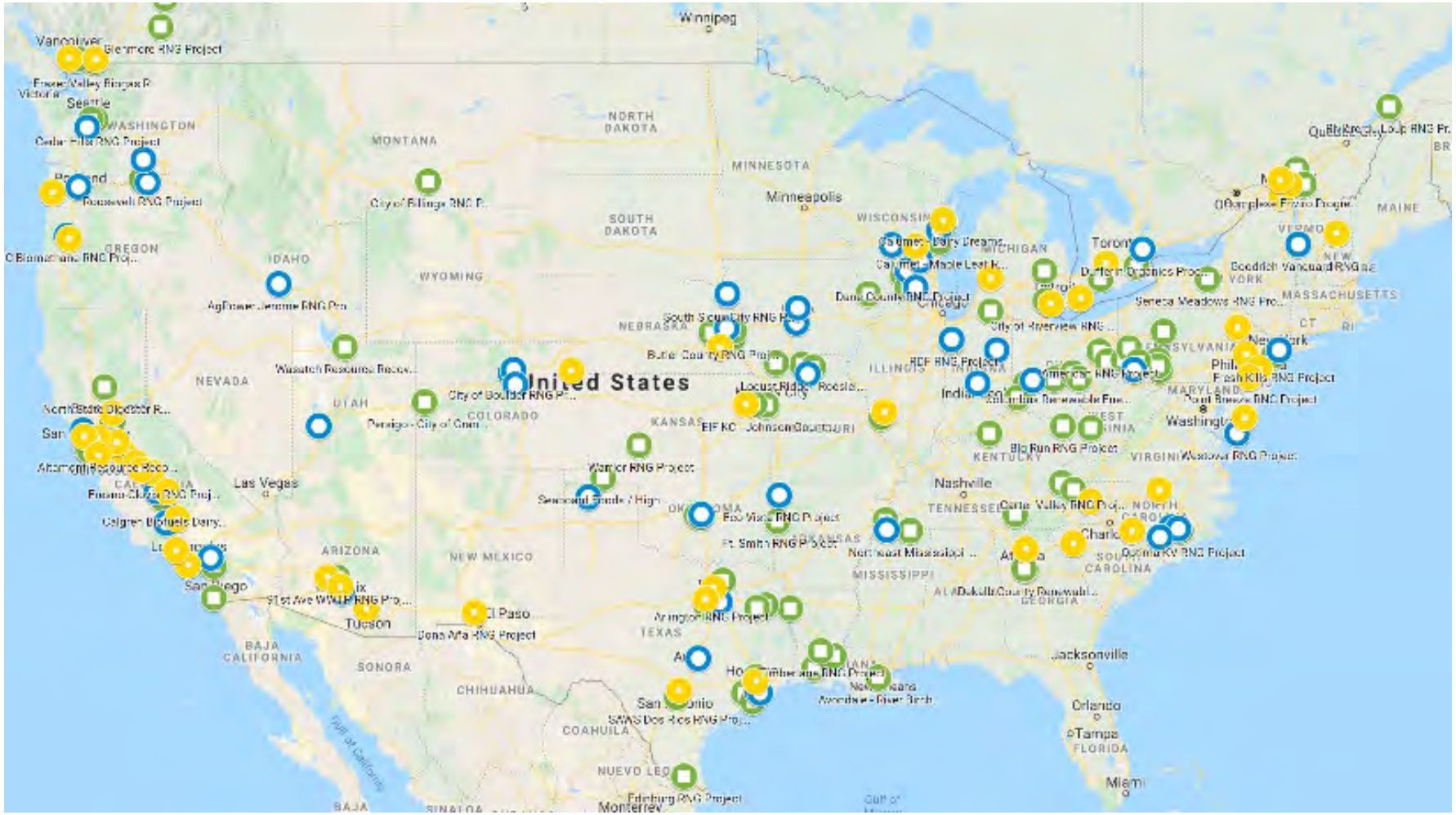
RNG Projects Nationwide



Nearly 200 RNG projects operating today, up from just 60 projects in 2017; ~120 more under development

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Value of NJ's RNG Resource

- 7 Large Landfills = 5.9 million mmbtu/yr
- 1.3 million tons food waste = 5.9 million mmbtu/yr
- 22 WWTPs = 1.5 million mmbtu/yr
- TOTAL of ~13.3 million mmbtu/yr or ~95 million gallons of diesel displacement potential

- **10% of TOTAL current on-road diesel consumption could be displaced using in-state resources**
- **Enough fuel to power ~10,000 heavy-duty vehicles and eliminate ~850,000 tons CO2e per year**

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RNG End Users

- **Transportation Market Driving Investments**

  CNG/LNG fleets expanding RNG use nationally; driven by RFS and LCFS credit value well above commodity gas pricing

- **Gas Utility Procurement Heating Up**

  A growing list of natural gas utilities across the country are developing RNG programs for residential and commercial customers

- **Voluntary CSR Commitments Emerging**

  Corporations, colleges and universities are recognizing the role RNG can play

SoCalGas

Vermont Gas

CenterPoint Energy

NW Natural

Port of Seattle

Middlebury

ENERGY VISION

Matt Tomich, President

email: tomich@energy-vision.org
tel: 212.228.0225
web: www.energy-vision.org

ENERGY VISION

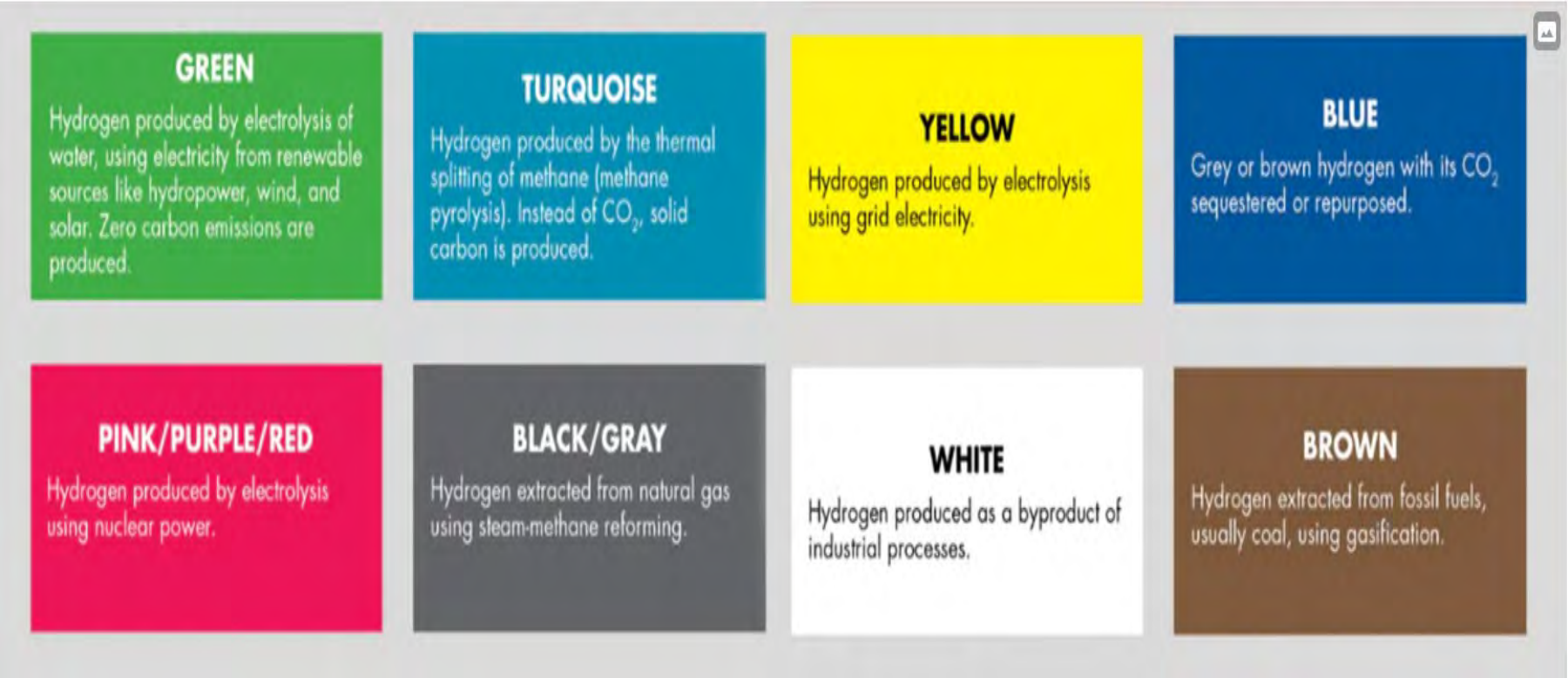
NJFCC
NEW JERSEY FUEL CELL
COALITION

Hydrogen

NJ Clean Cities/Energy Vision Workshop
Decarbonizing Gas in New Jersey
November 4, 2021

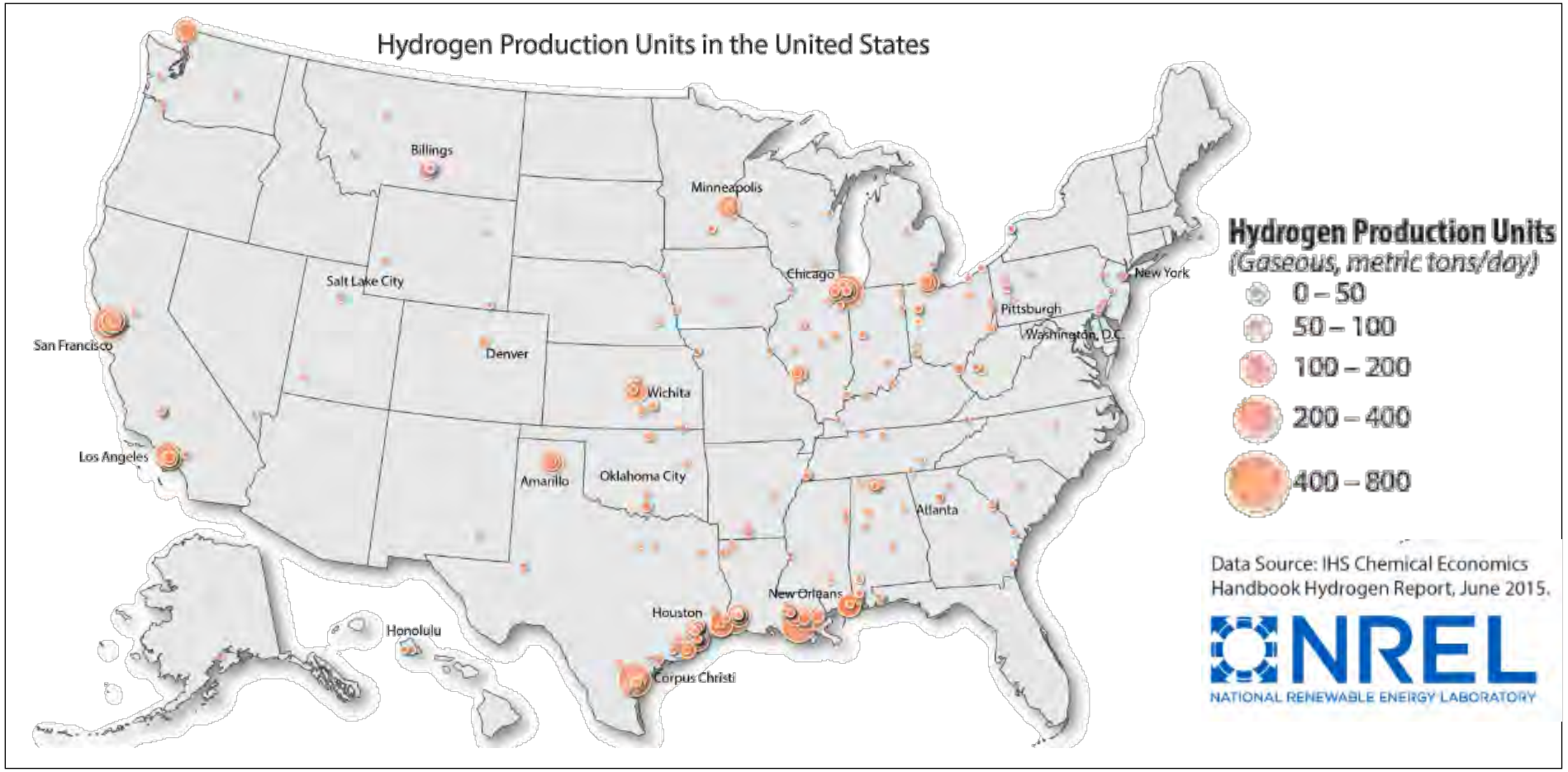
JoAnn Milliken
Director
NJ Fuel Cell Coalition

Hydrogen can be produced in many ways



Color Code Source: North American Council for Freight Efficiency

Hydrogen is an industrial commodity



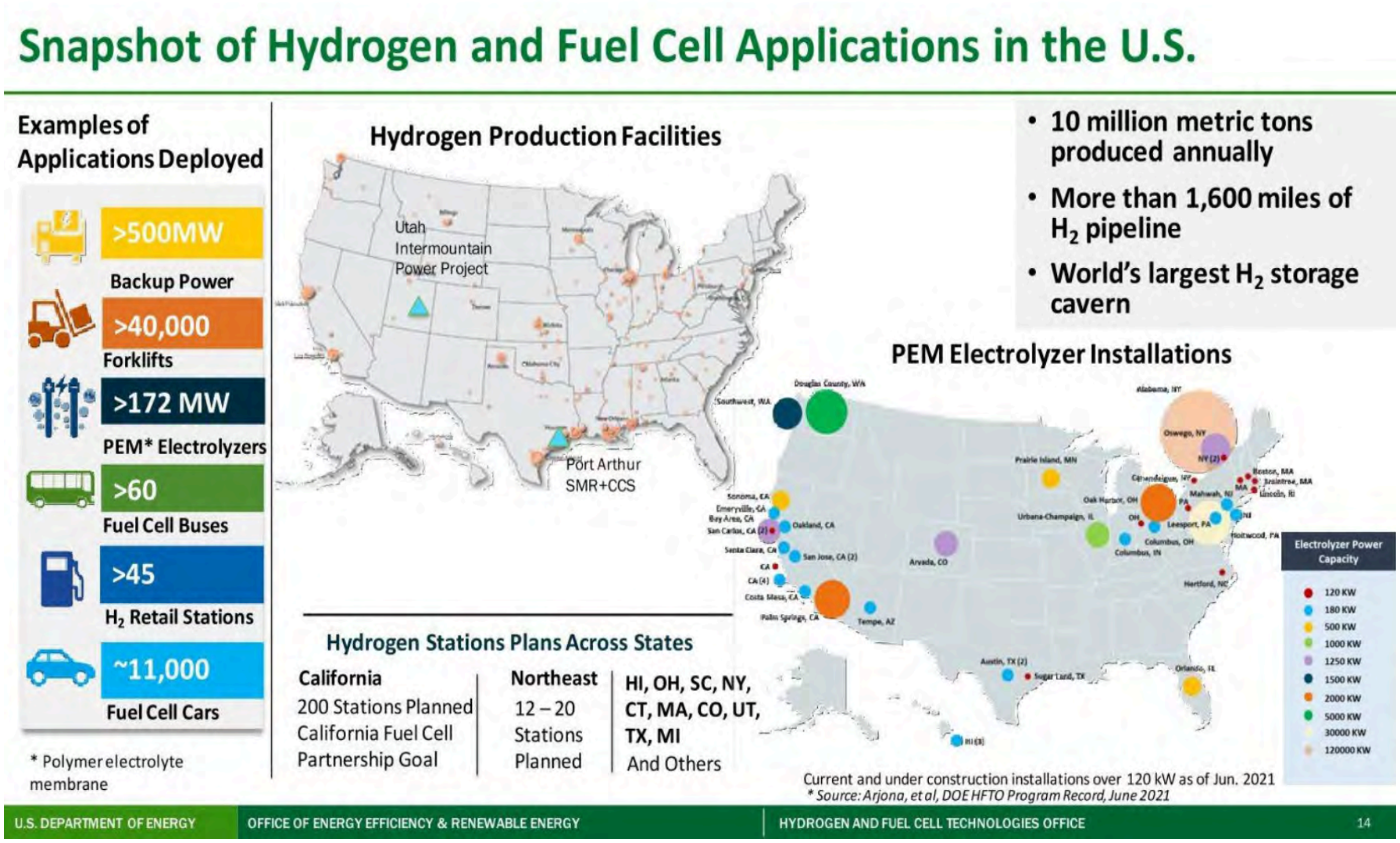
U.S. annual hydrogen production

10 million metric tons

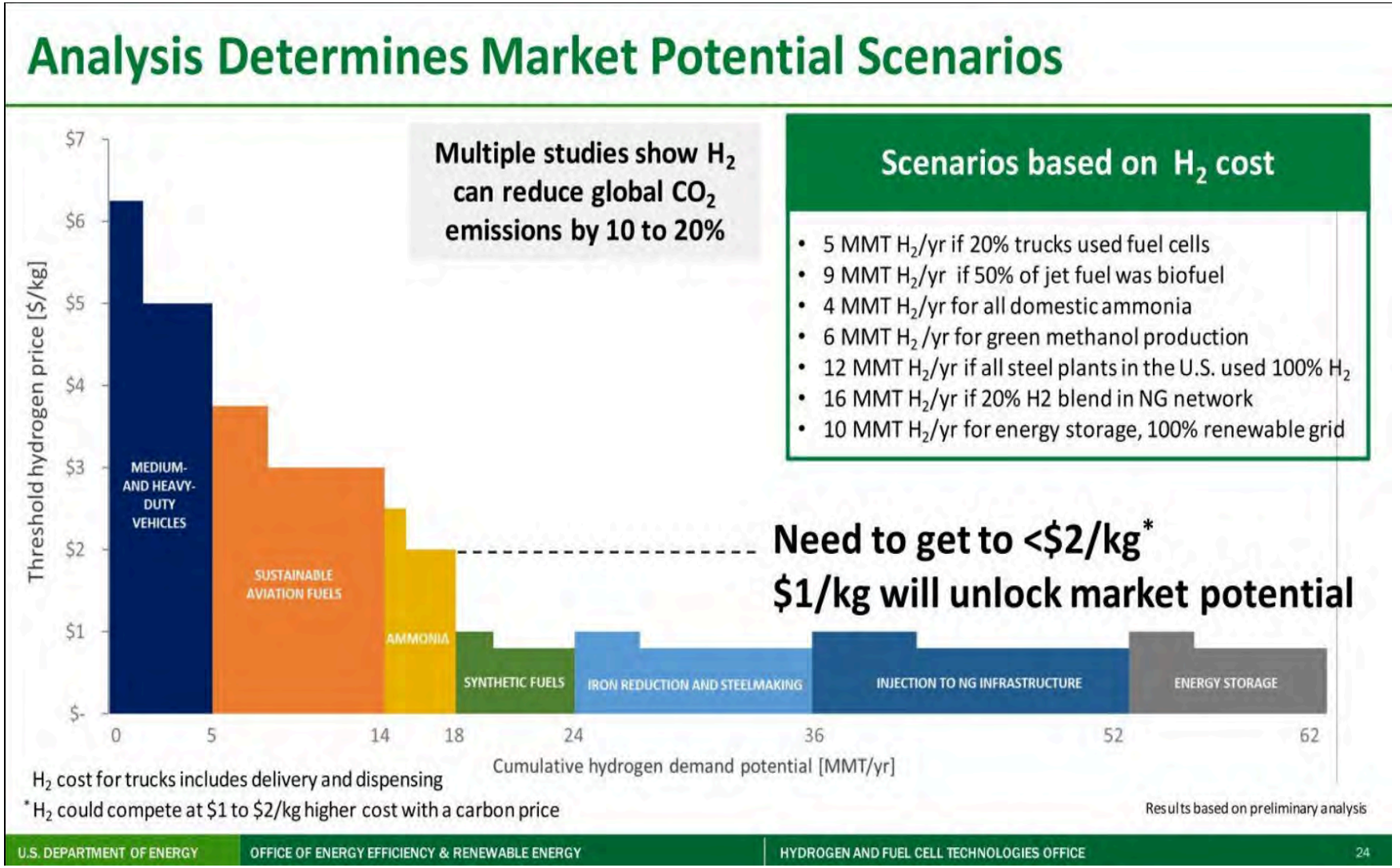
Largest users in the U.S.

Petroleum Processing	68%	Fertilizer Production	21%

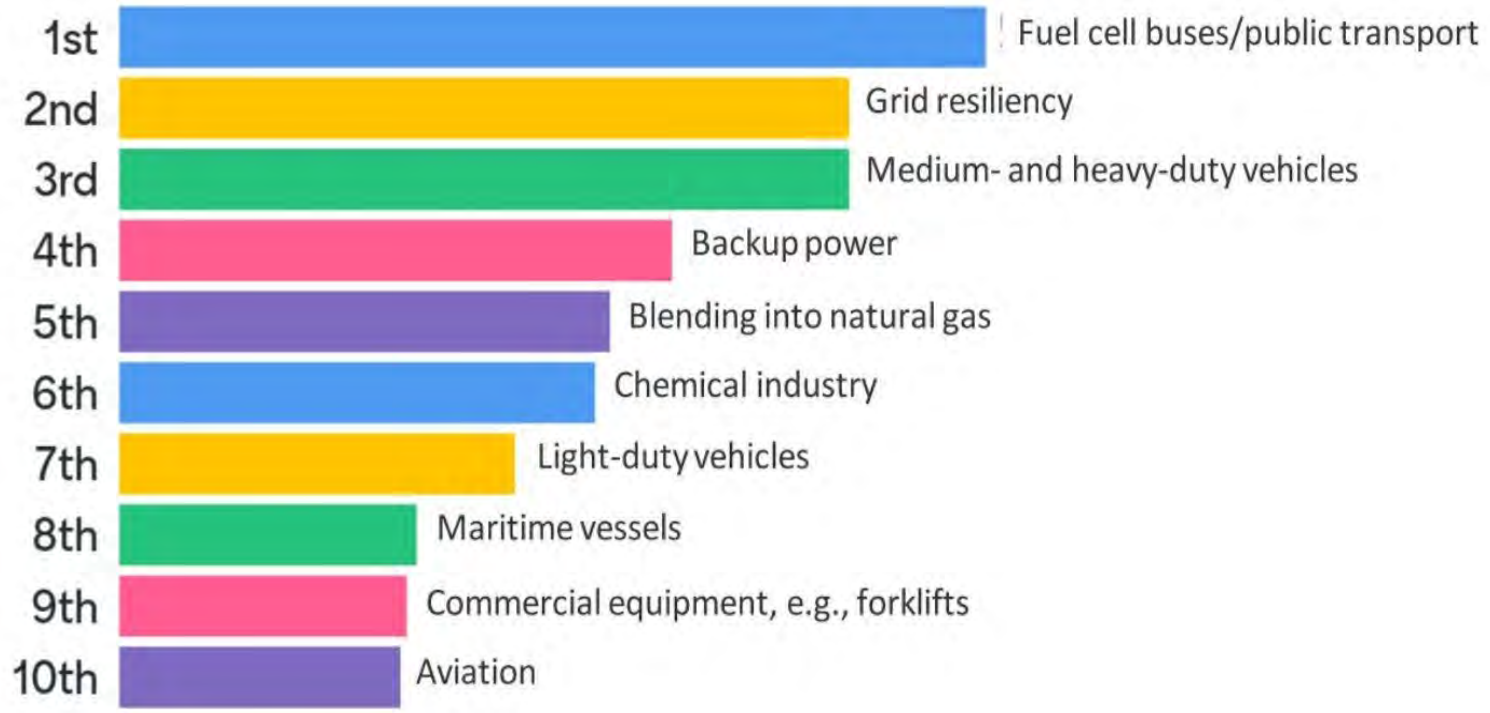
Fuel Cells powered by hydrogen are highly efficient and scalable



Hydrogen cost must come down to be competitive in most markets



Hydrogen can help Underserved Communities

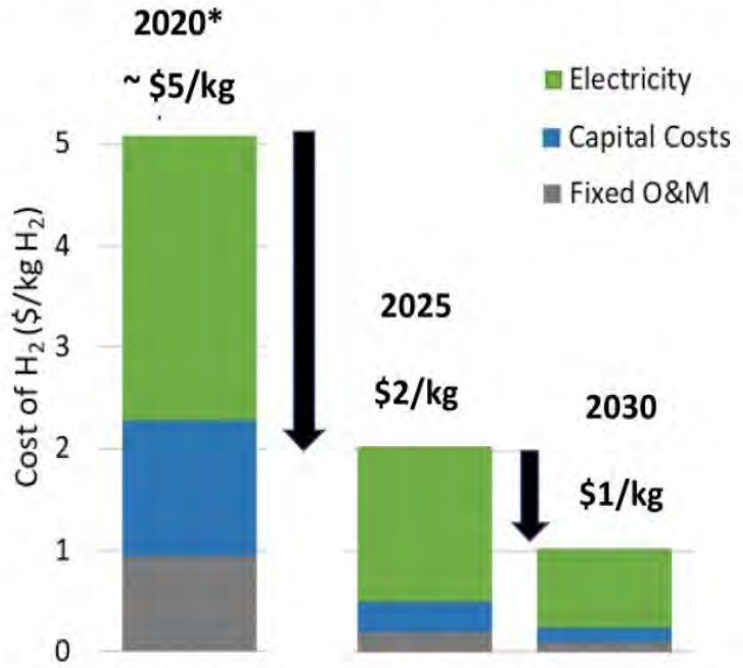


earthshots | Hydrogen

Source: Wieliczko, et al, DOE HFTO

Significant reduction in cost of electrolysis is needed for Green Hydrogen

Example: H_2 Cost from PEM Electrolysis

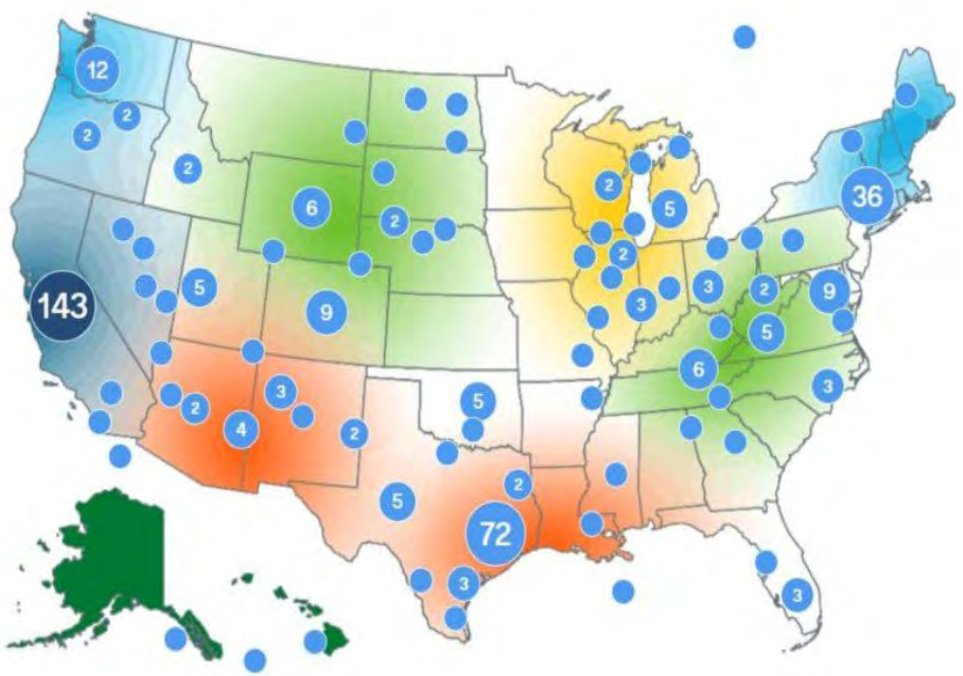


Pathways to meet Goal

- Reduce electricity cost and improve efficiency and utilization
- Reduce capital cost >80%
- Reduce operating & maintenance cost >90%

*2020 Baseline: PEM (Polymer Electrolyte Membrane) low volume capital cost ~$1,500/kW, electricity at $50/MWh. Pathways to targets include capital cost < $300/kW by 2025, < $150/kW by 2030 (at scale). Assumes $50/MWh in 2020, $30/MWh in 2025, $20/MWh in 2030

The Northeast is a prime location for large-scale hydrogen demos



ENERGY earthshots | Hydrogen
U.S. DEPARTMENT OF ENERGY

Source: Wieliczko, Harting, et al, DOE HFTO

Thank You

JoAnn Milliken
NJ Fuel Cell Coalition
njfuelcells.org

Propane Education & Research Council

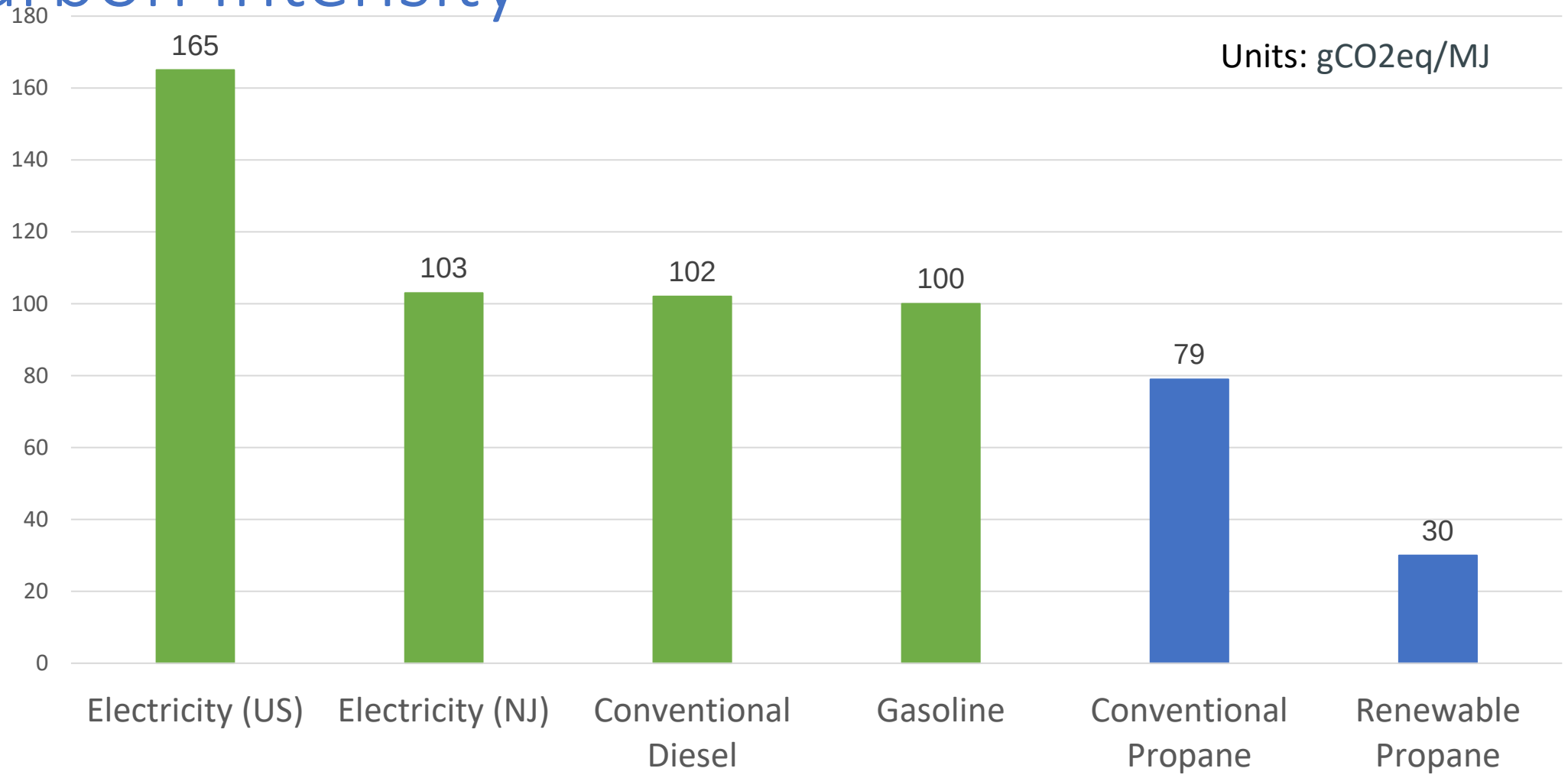
Powering Vehicles with Renewable Propane

Tucker Perkins

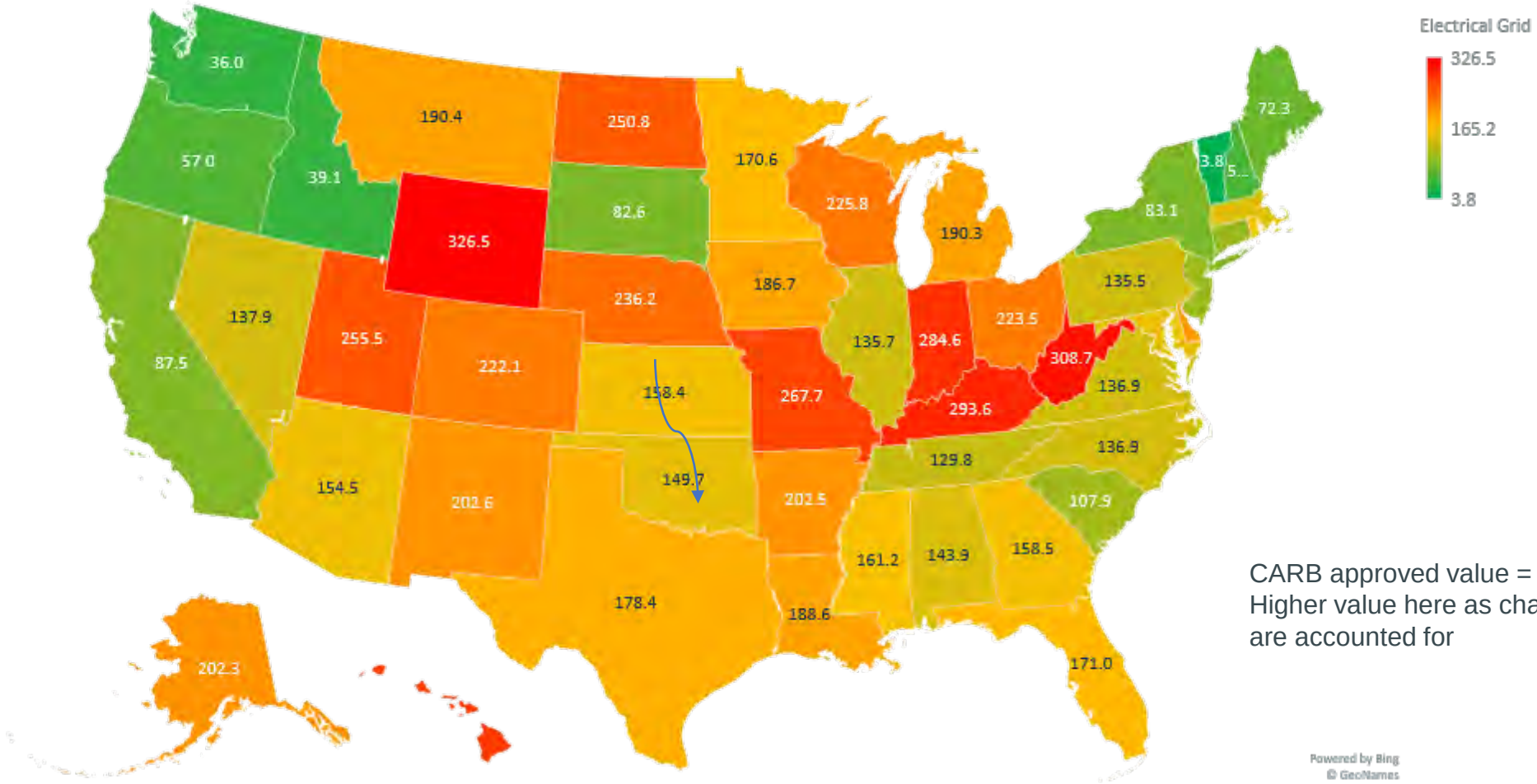
President and CEO
Propane Education & Research Council

ENERGY FOR EVERYONE
propane

Carbon Intensity



Well-to-Wheels Carbon Intensity of Today's Electricity Grid ($gCO2_{eq}/MJ$)



CARB approved value = 82.92.
Higher value here as charging losses are accounted for

Source: *Decarbonization of MD-HD Vehicles with Propane* by Gokul Vishwanathan, PERC, October 2020

Renewable Propane

- Low carbon intensity
- Inexpensive feedstock
- Abundant feedstock
- Low energy conversion
- Final product competitively priced

Renewable Propane Production

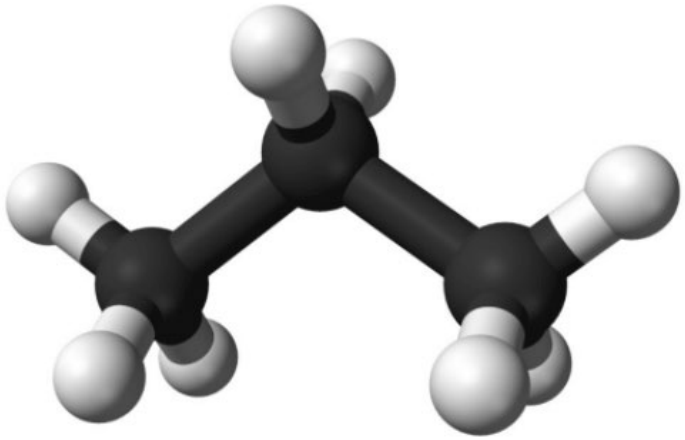
Producer	Location	Renewable propane capacity (Millions Gallons)	Status 2020
BP	Blaine, WA	2.7	Operating
Diamond Green Diesel	Norco, LA	5.4	Operating
Diamond Green Diesel	Port Arthur, TX	48.2	Start-up 2024
Global Clean Energy Holdings	Bakersfield, CA	18.8	Onstream late 2021
HollyFrontier	Cheyenne, WY	10.7	Start-up early 2022
HollyFrontier	Artesia, NM	13.4	Start Q1 2022
Kern Oil & Refining	Bakersfield, CA	NA	Unknown
Tesoro Marathon	Dickinson, ND	0.8	Operating
Marathon	Martinez, CA	36.8	
Next Renewable Fuels	Portland, OR	80	Unknown
Philips 66	Rodeo, CA	34	
Renewable Energy Group	Geismar, LA	10.1	Operating
Seaboard Energy		8.9	Q4 2021
Sinclair	Sinclair, WY	14.8	Operating
World Energy	Paramount, CA	3.8	Operating
	Potential Capacity Sum	288.4	

Pathways for Renewable Propane

- Gasification – syngas, from biomass
- Gasification – syngas, from waste
- Pyrolysis from biomass
- Glycerin-to-propane
- Power-to-X
- Biogas Oligomerization
- Alcohol to jet/LPG
- * Plus ammonia, DME, hydrogen, etc.

Carbon-Neutral Cocktail – The Future?

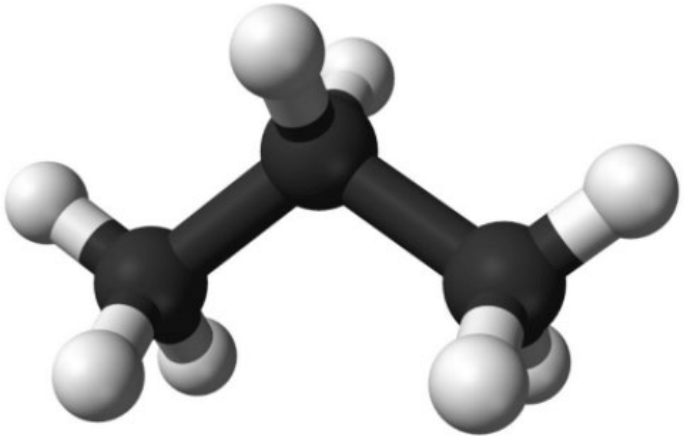
80 gCO2eq/MJ



Conventional
~30% by mass

+

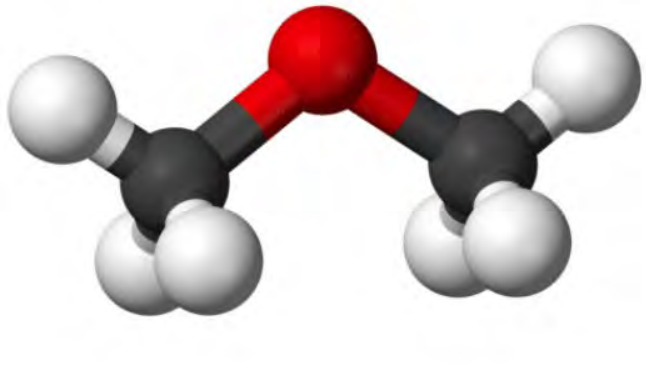
20.5 gCO2eq/MJ



Renewable
(NA Sourced used cooking oil)
~50% by mass

+

-278 gCO2eq/MJ



Renewable
(Dairy gas based)
~20% by mass

~0 gCO2eq/MJ

- Precision Energy

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President & CEO

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DECARBONIZING GAS IN NEW JERSEY WORKSHOP

Argonne NATIONAL LABORATORY

Emissions of Renewable Natural Gas and Hydrogen

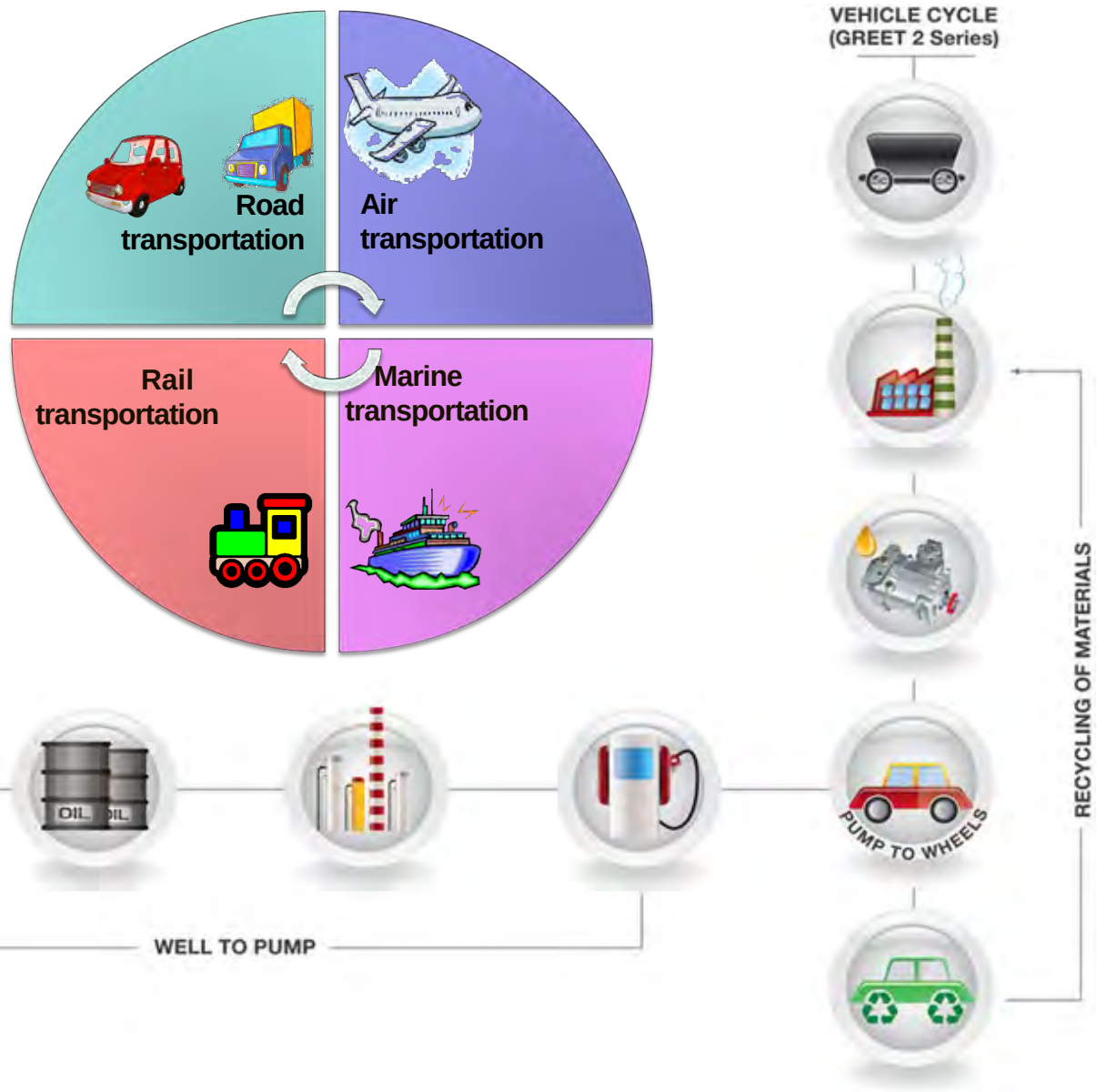
ANDY BURNHAM
Principal Environmental Scientist
aburnham@anl.gov

November 4, 2021

GREET Model

- GREET analyzes transportation and energy systems:
  - Energy use
  - Greenhouse gases
  - Air pollutants
  - Water consumption

- GREET free and public domain: greet.es.anl.gov
  - Updated and expanded annually



AFLEET Tool

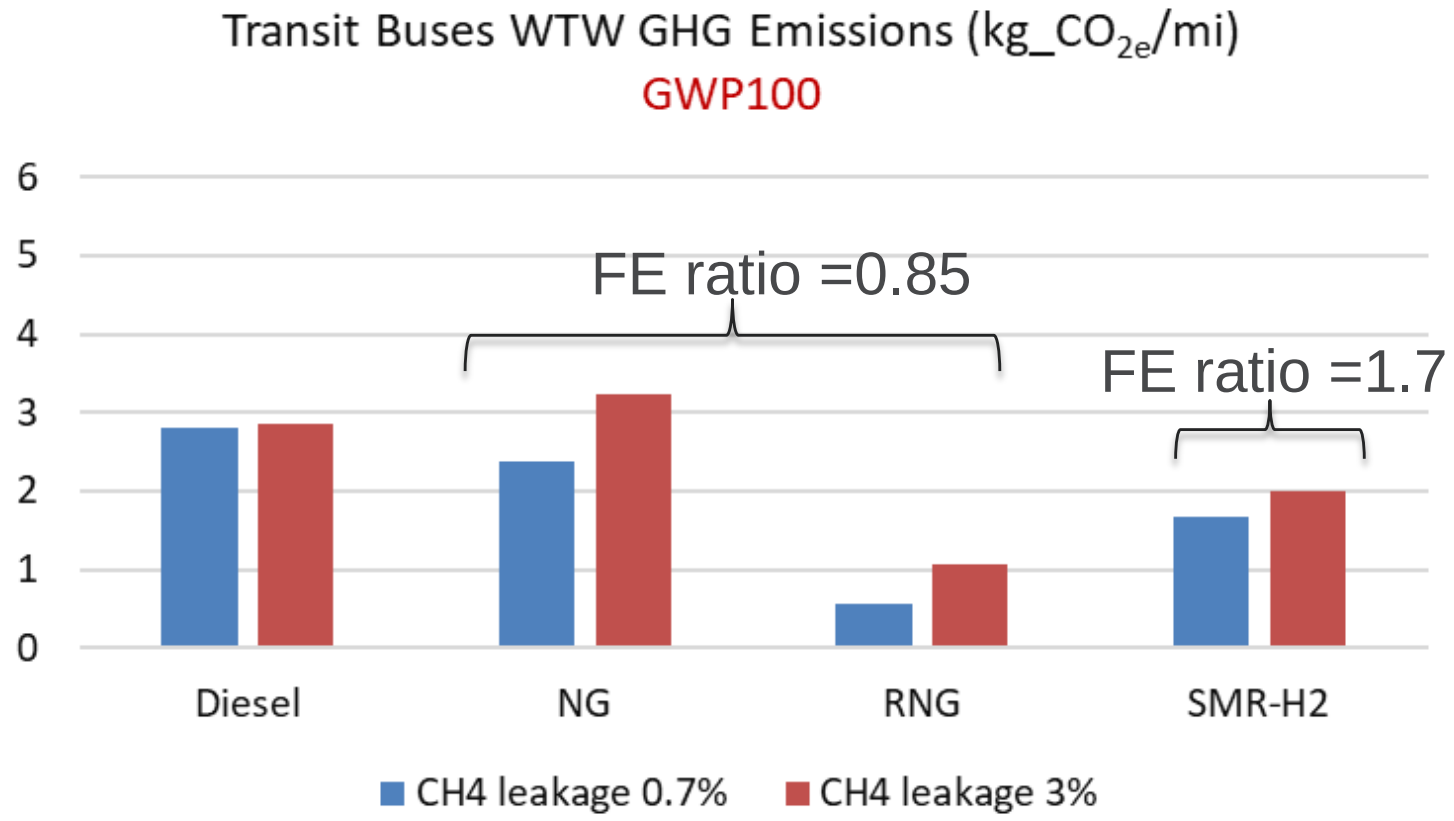
- Examines light-duty & heavy-duty & off-road vehicle:
  - Petroleum use
  - GHGs
  - Air pollutants
  - Cost of ownership

- Contains 18 fuel/vehicle technologies
  - Conventional
  - Hybrids
  - Plug-in electrics
  - Alternative fuels: **CNG, LNG, H_2,** LPG, ethanol, biodiesel, renewable diesel

    - NG = fossil, landfill, animal waste, wastewater sludge, MSW
    - H_2 = SMR, electrolysis

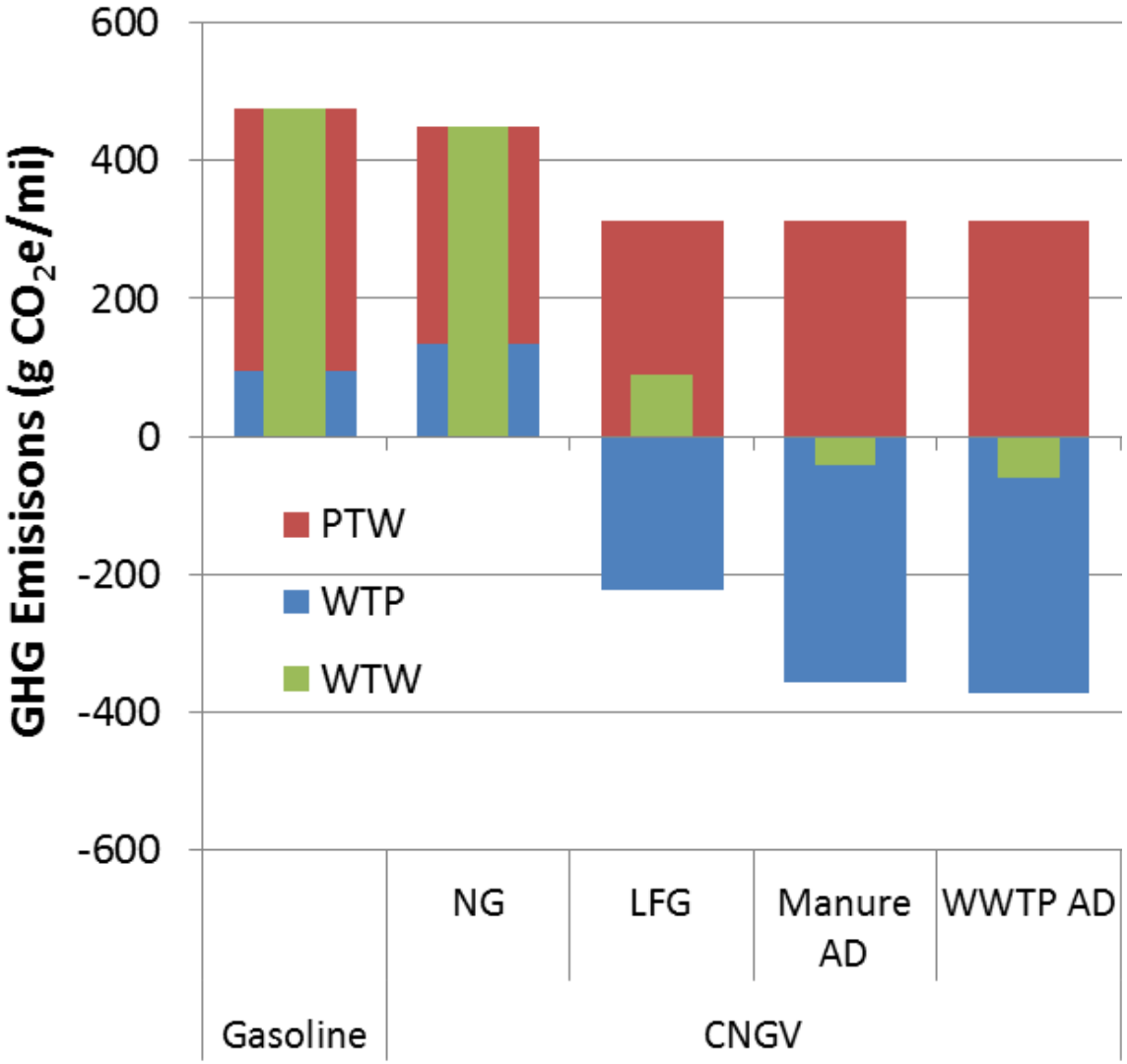
- AFLEET Spreadsheet and Online; HDVEC: afleet.es.anl.gov

NG Source & Leakage impact NGV GHG Performance

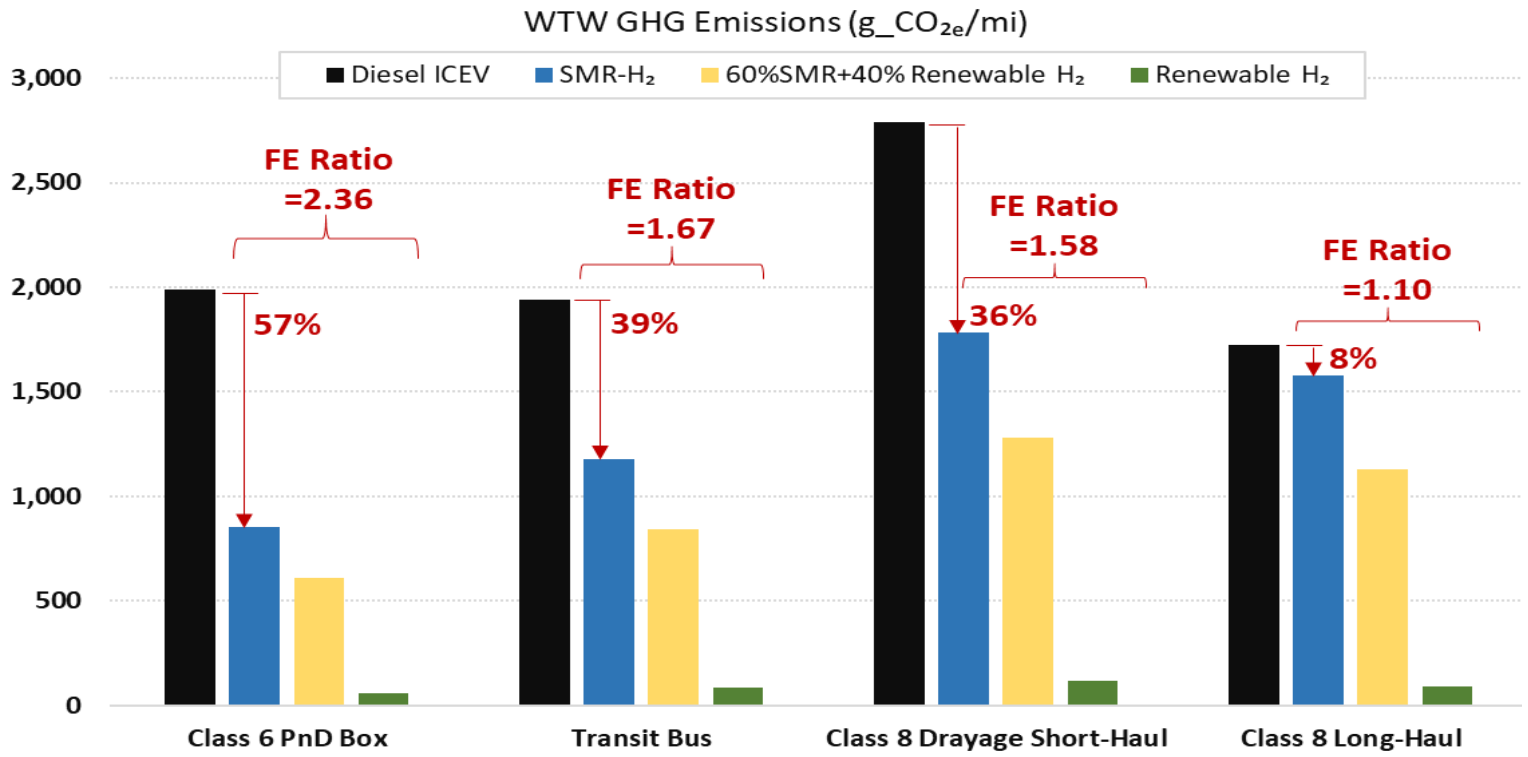


- Potential production of RNG ~3.6 to 6.5 billion DGE/yr
  - Could cover 10-15% of US on-road diesel consumption
  - Cost challenges when scaling up production

RNG Source impacts NGV GHG Performance



H_2 Source & Fuel economy ratio impact FCV GHG Performance



- Current H_2 production potential (RFF 2020)
  - Biomass: ~ 1/6 one-sixth of technical potential of US biomass
  - Electric: ~ 1% of wind / 0.1% of solar
    - Current production cost NG SMR $1-1.5/kg; wind $2.5-4.5; solar $3.5-$7
    - Electrolyzer cost and capacity factor

THANK YOU!!!

Argonne National Laboratory's work is supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy

This work has been supported and assisted by:

Margaret Smith: U.S. DOE

Amgad Elgowainy: Argonne

Marcy Rood: Argonne

Joann Zhou: Argonne

Decarbonizing Gas in New Jersey

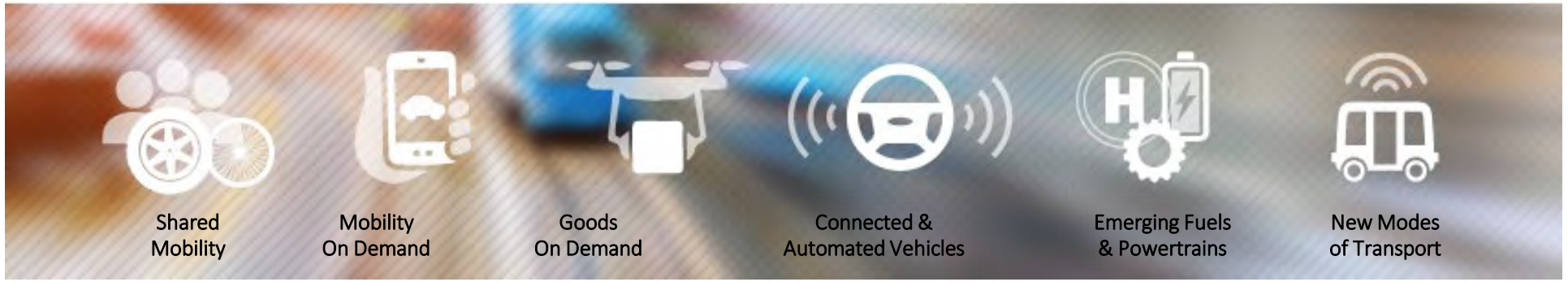
November 4, 2021

New Jersey Clean Cities
Decarbonizing Gas in New Jersey

John Gonzales
National Renewable Energy Laboratory
John.gonzales@nrel.gov
https://cleancities.energy.gov

NEW TECHNOLOGIES & BUSINESS MODELS ARE

DRIVING DISRUPTION



Portfolio


Fuel Economy
E
F
Reduce
Replace
Clean Cities
U. S. Department of Energy
Eliminate
Idle Reduction
Biodiesel
Electricity
H2
Hydrogen
Natural Gas
LPG
Propane
Ethanol

Electricity

- Zero tailpipe emissions
- Mostly LD vehicles; MD/HD market is growing
- Low operating costs
- Can be renewable
- Delivered by widespread electric grid

Natural Gas (RNG)

- Fuel economy similar to gasoline
- Driving range competitive with gas/diesel
- Fuel cost competitive and stable
- Commonly MD/HD vehicles
- Can be renewable – livestock/landfill
- Delivered by widespread pipelines

Propane (Renewable LPG)

- MD niches
- Off-road (ex: mowers, forklifts)
- Lower maintenance costs
- Low cost fueling infrastructure
- Renewable sources in development
- Delivered by truck

Hydrogen (Renewable H2)

- Zero tailpipe emissions (fuel cell electric vehicles)
- Fast-filling time
- Driving range comparable to diesel
- Low market penetration; mostly in CA
- Produced from water or hydrocarbons
- High cost vehicles and infrastructure

National Alternative Fuel Corridors

- To improve the mobility of alternative fuel vehicles, the U.S. Department of Transportation (DOT) has designated national corridors in strategic locations along major highways for:
  - Plug-in electric vehicle charging
  - Hydrogen fueling
  - Propane (LPG) fueling
  - Natural gas (CNG, LNG) fueling

Complementary Framework

Local & National Partnerships

Information & Education

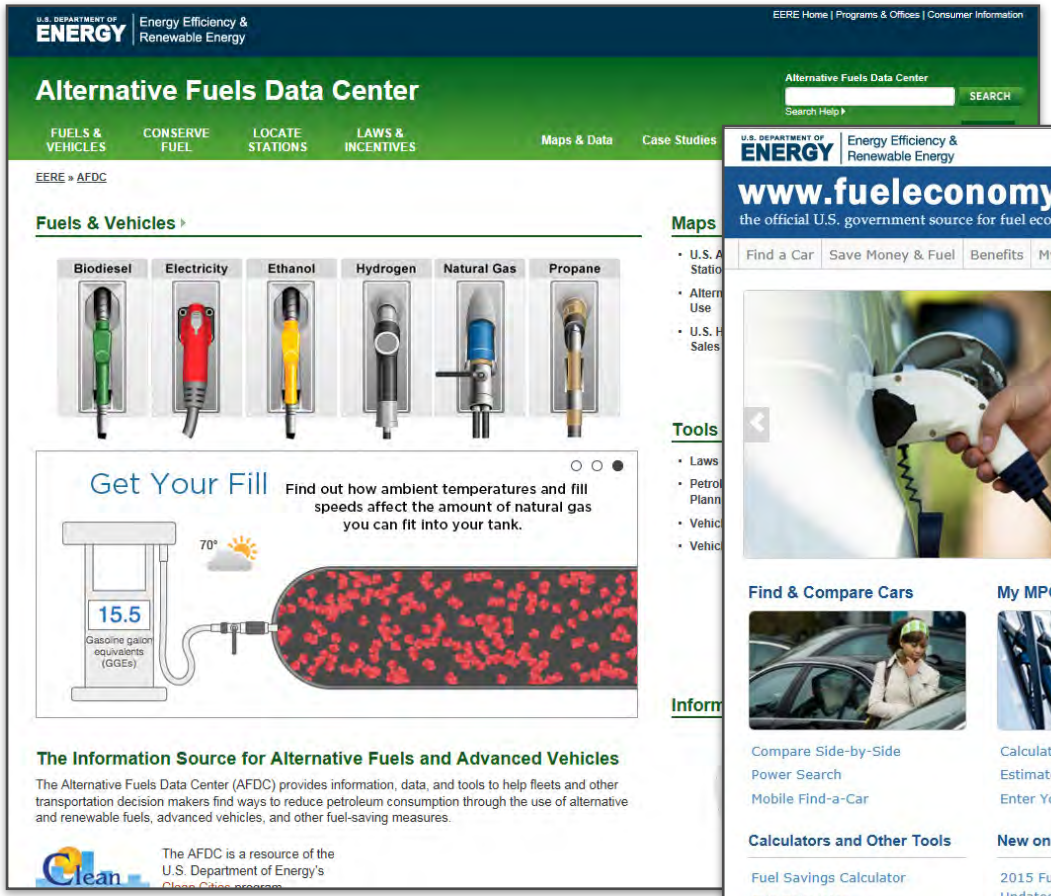
Competitively Awarded Financial Assistance

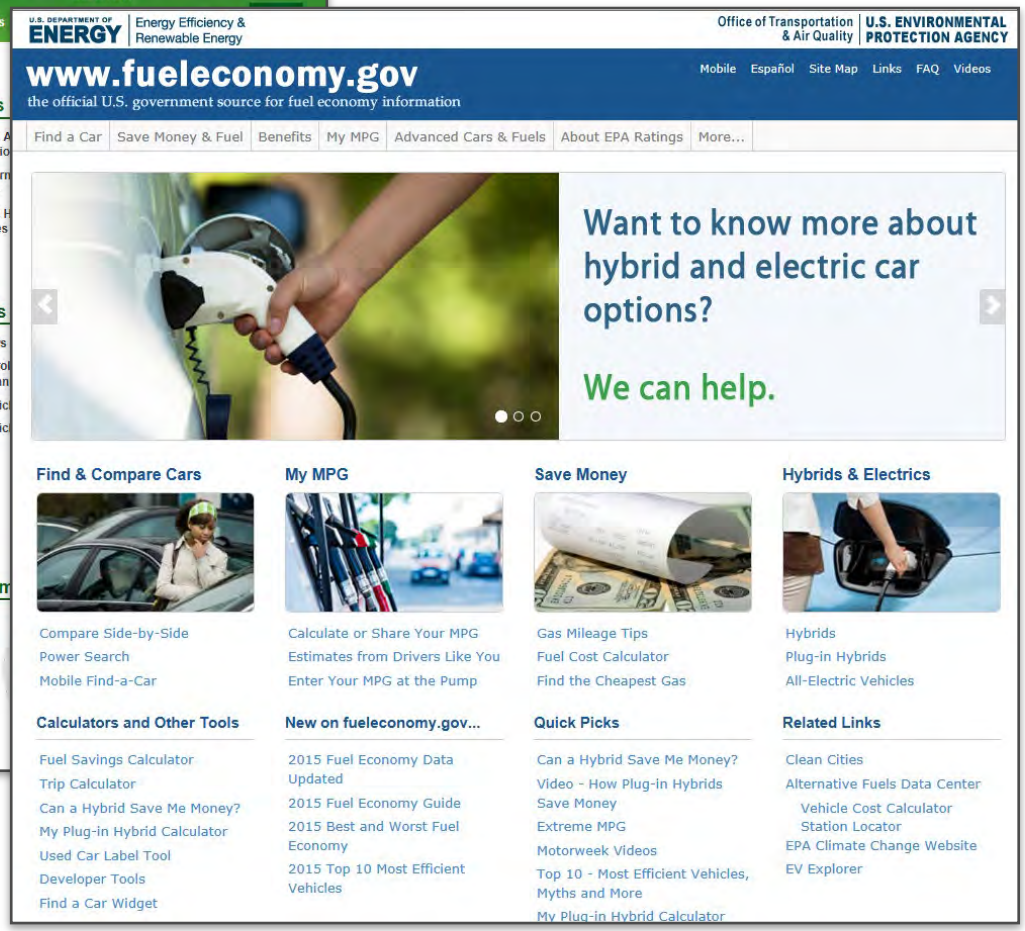
Technical & Problem Solving Assistance

Clean Cities coalitions are locally based with the ability to tap national resources.

Information & Education: Websites

afdc.energy.gov





FuelEconomy.gov

Clean Cities: Making the Connections

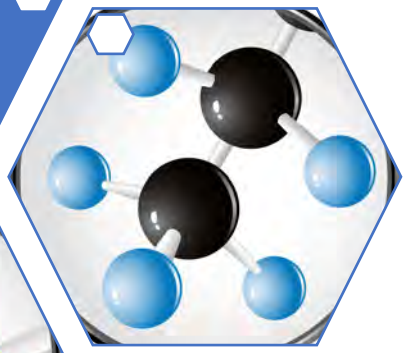
Clean Cities

Department of

Local & National Partnerships

Information & Education

Competitively Awarded Funding



Technical & Problem Solving Assistance

Advancing Low Carbon Gases Today: Industry Perspective

- Dan Hagan – Waste Management Organics
- Mark Kahrer – New Jersey Natural Gas
- Panel discussion

WASTE MANAGEMENT

New Jersey Natural Gas

ORGANICS RECYCLING

WASTED FOOD IS WASTED ENERGY™

Large Scale Solutions to Solve Food Waste & Organic Recycling for Renewable Fuel Generation

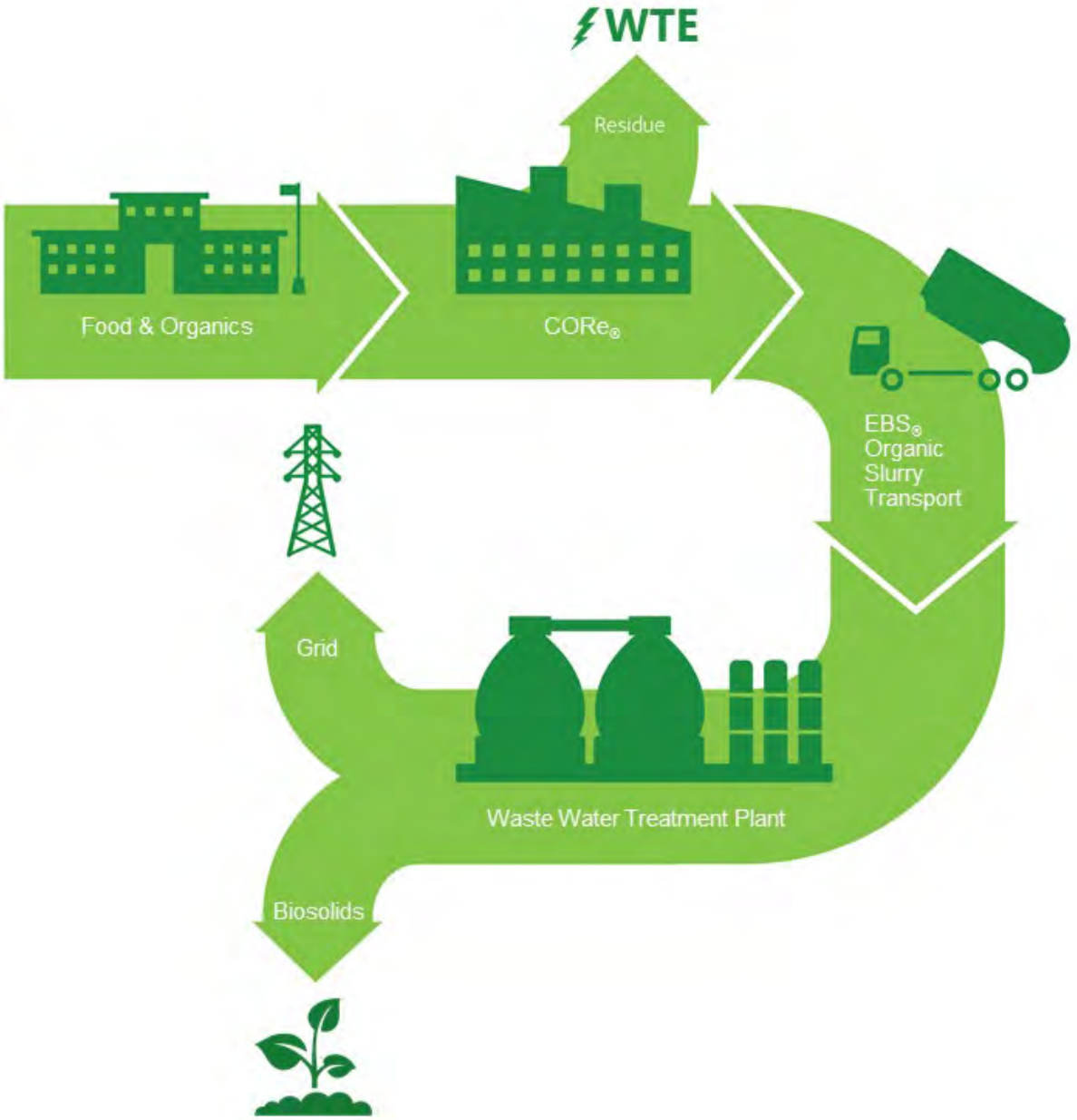
Dan Hagen, Director of Business Development WM Organics

Decarbonizing Gas in New Jersey

November 4, 2021

WM CORe® System

WM CORe®
ORGANIC
PROCESSING



Waste Management's CORe® process is a local, urban solution that takes food material and through our proprietary process we convert that material into our EBS® product

EBS® is a high quality, consistent product that removes >99.9% of the physical contaminants >4mm found in urban food waste

The EBS® product is used to create renewable, sustainable energy in partnership with long term local partnerships, helping them approach zero waste

1 ton of inbound SSO, processed to produce our EBS® product, generates enough renewable, sustainable electrical energy to power 8 to 10 homes (or 3+ mmbtu)

WASTE MANAGEMENT

WM CORe® Inbound Source Separated Organic Food Waste

WM CORe® Residuals Separation

Contaminants Removed

Contamination Detail

WM WASTE MANAGEMENT

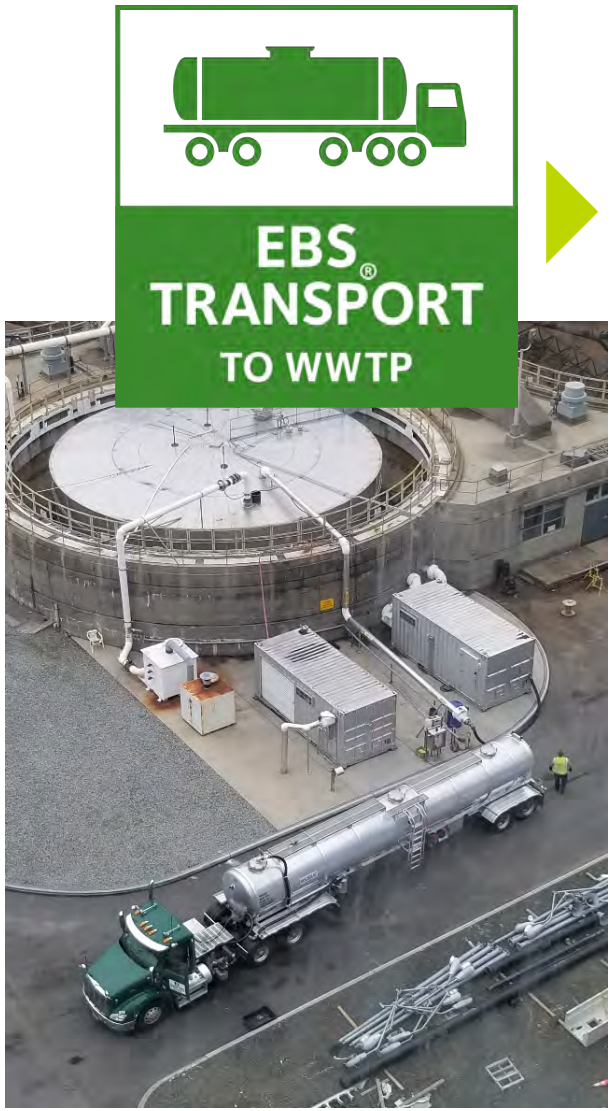
Food Waste

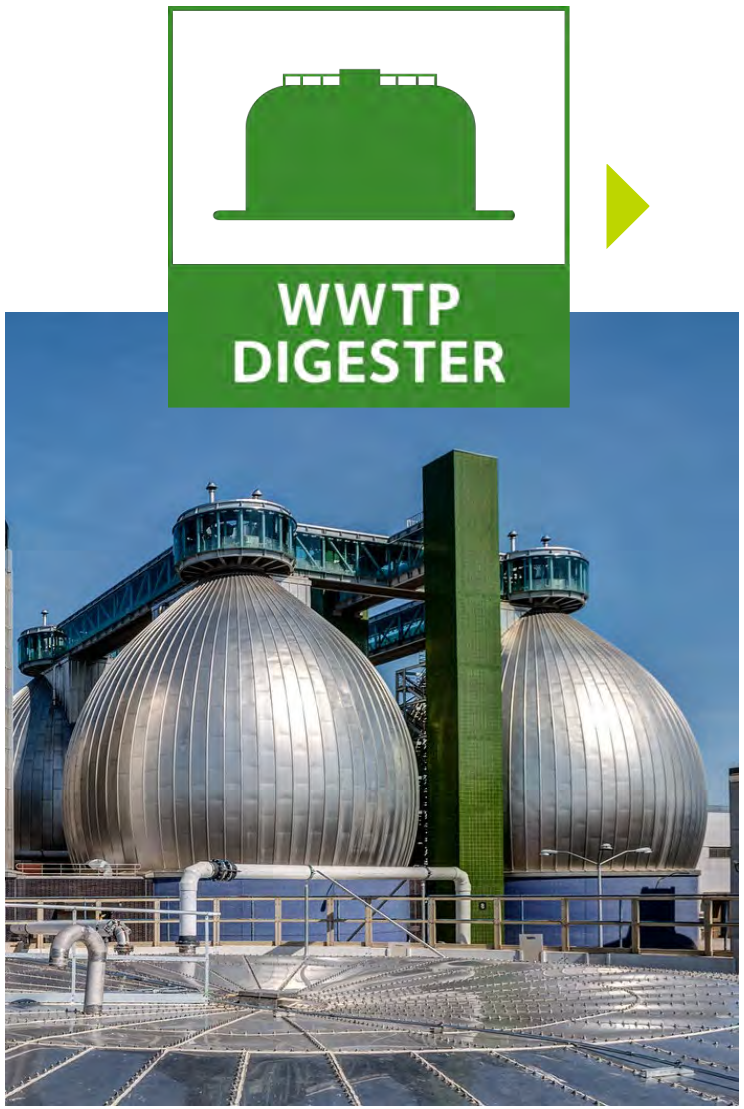
EBS® for Renewable Energy Production

Focused on developing a consistent product, removing contamination to produce a known energy content end product EBS®

WASTE MANAGEMENT

WM CORe® Co-digestion/Renewable Energy Production





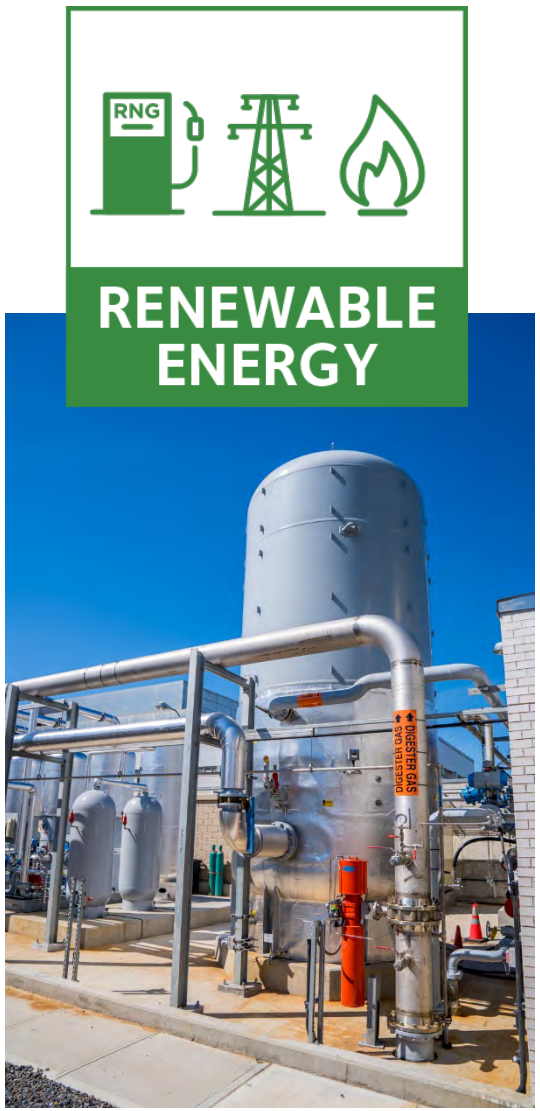
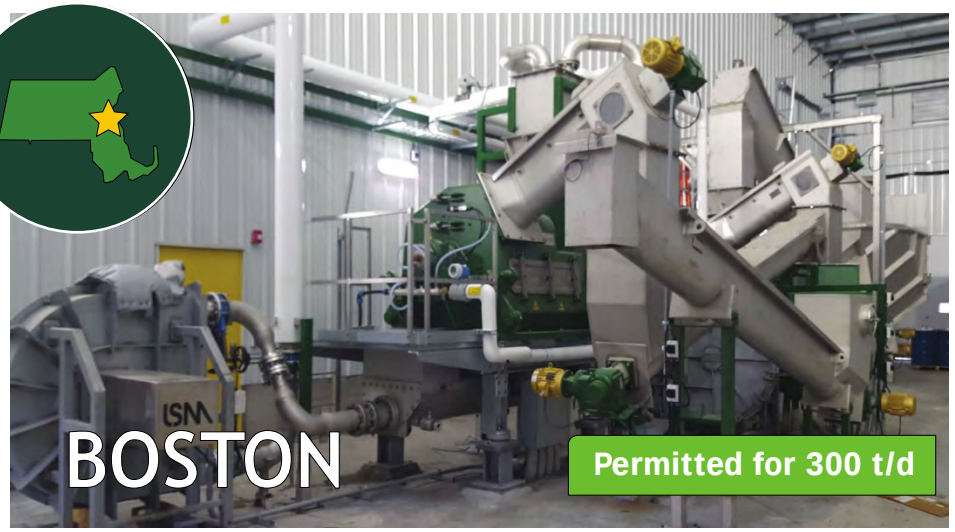
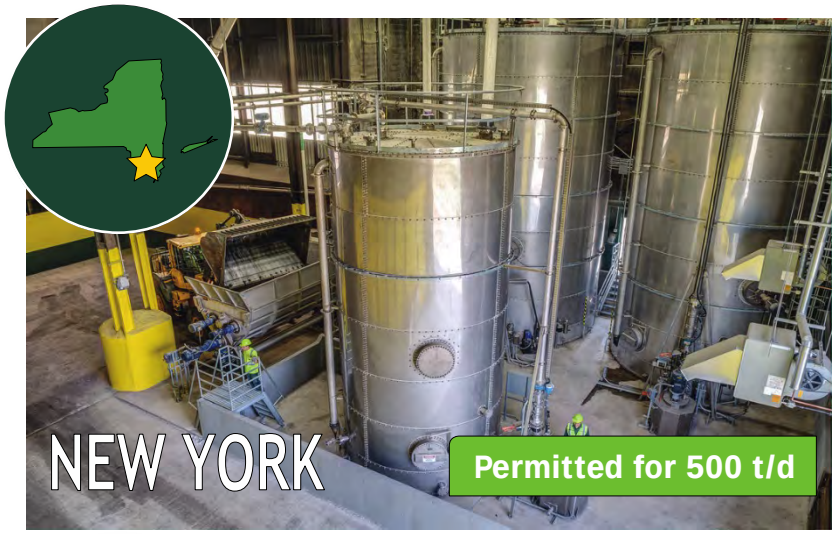
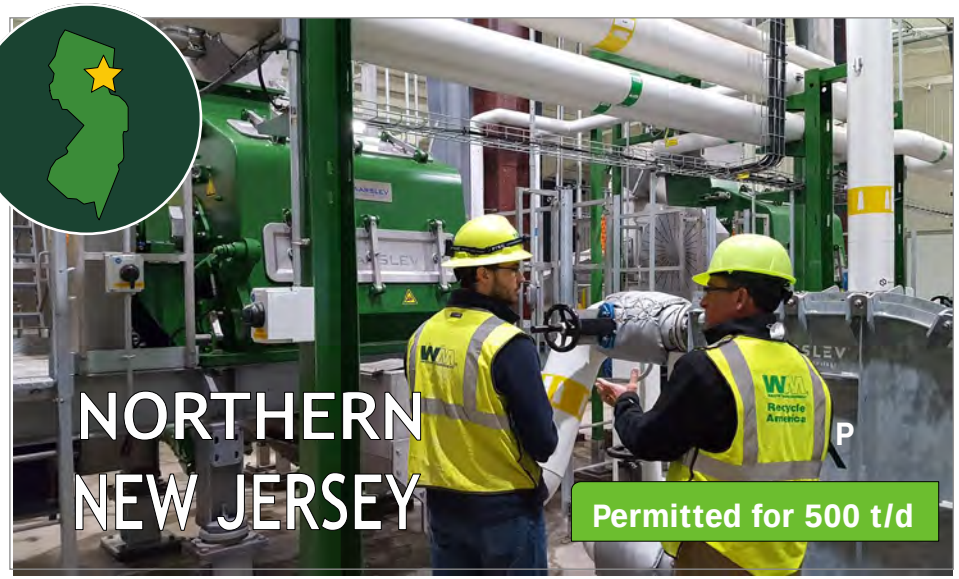


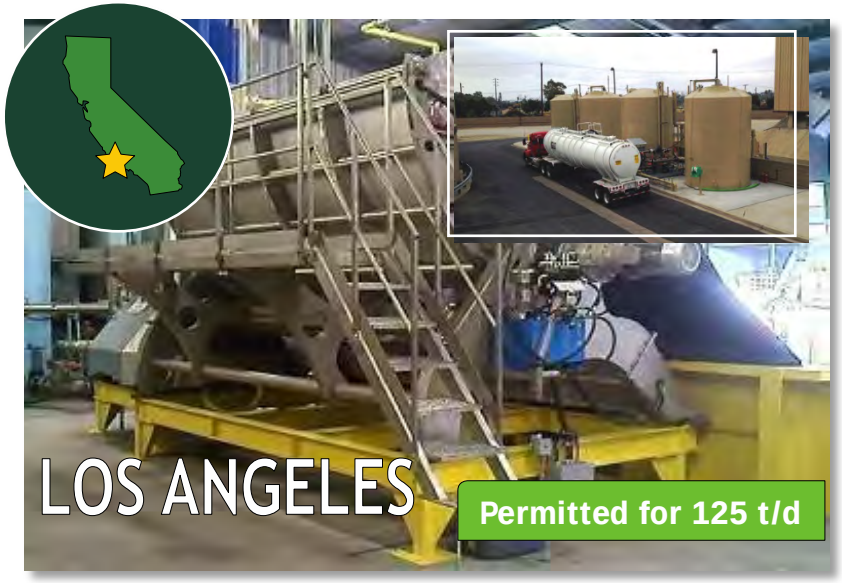
Photo Courtesy of NYCEP

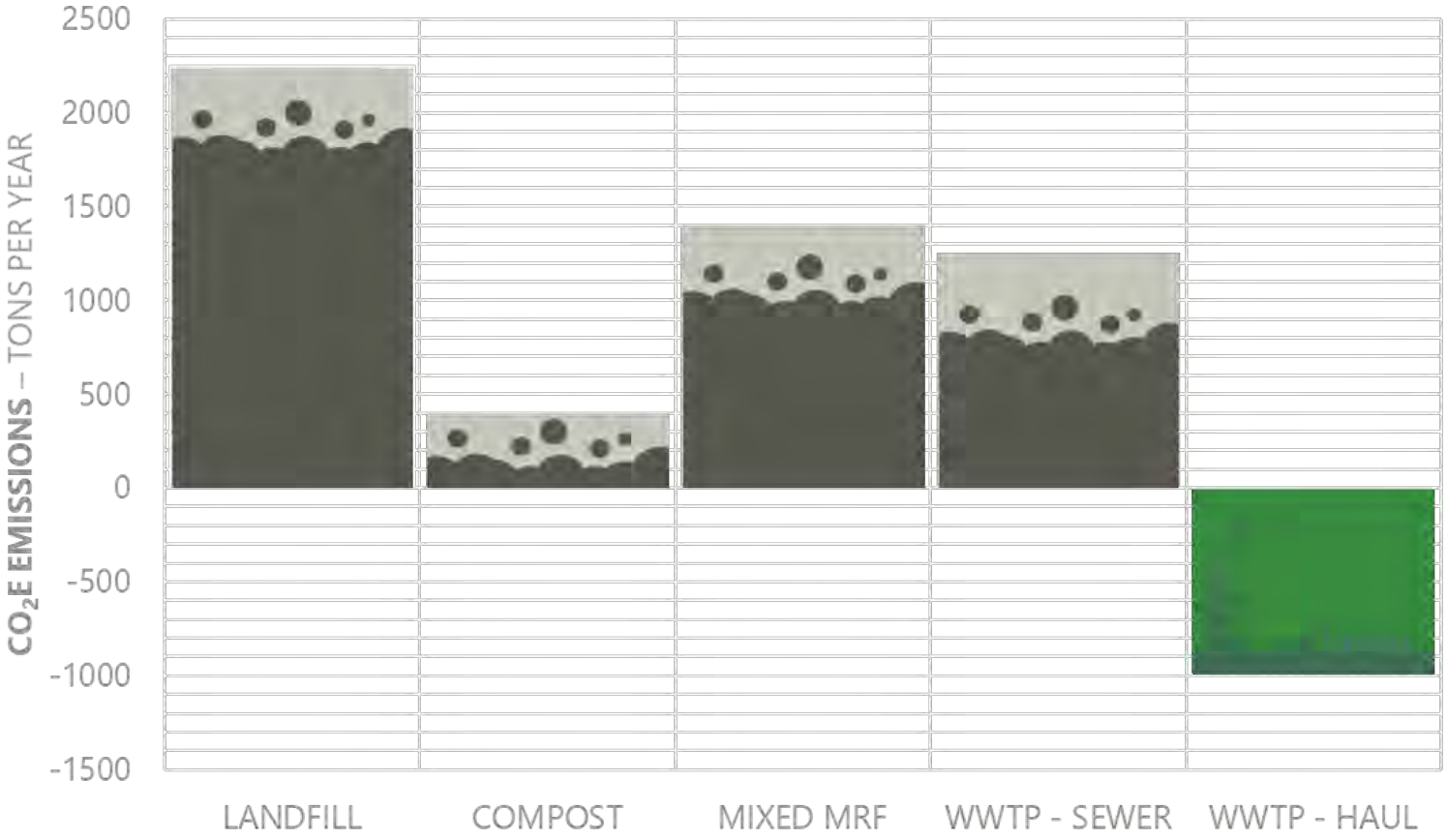
WM CORe® Operating Facilities











"From a carbon footprint comparison, the WWTP/Hauler alternative had the lowest carbon dioxide equivalent (CO_2E) emissions compared to the other alternatives"

THE Water Research FOUNDATION

In New Jersey, WM has 224 CNG vehicles with fueling stations in Camden, Trenton, Matawan and Toms River. WM will be adding stations in Lafayette and Woodbine in 2022.

With our current NJ fleet, we have reduced diesel fuel consumption by 1,792,000 gallons and 3,136 Metric Tons of greenhouse gas emissions annually.

WM WASTE MANAGEMENT

CORe® Process

Thank you!

Dan Hagen, Dir. Business Development
dhagen@wm.com
315.521.2631

Decarbonized Gas: The Potential for New Jersey

New Jersey Resources

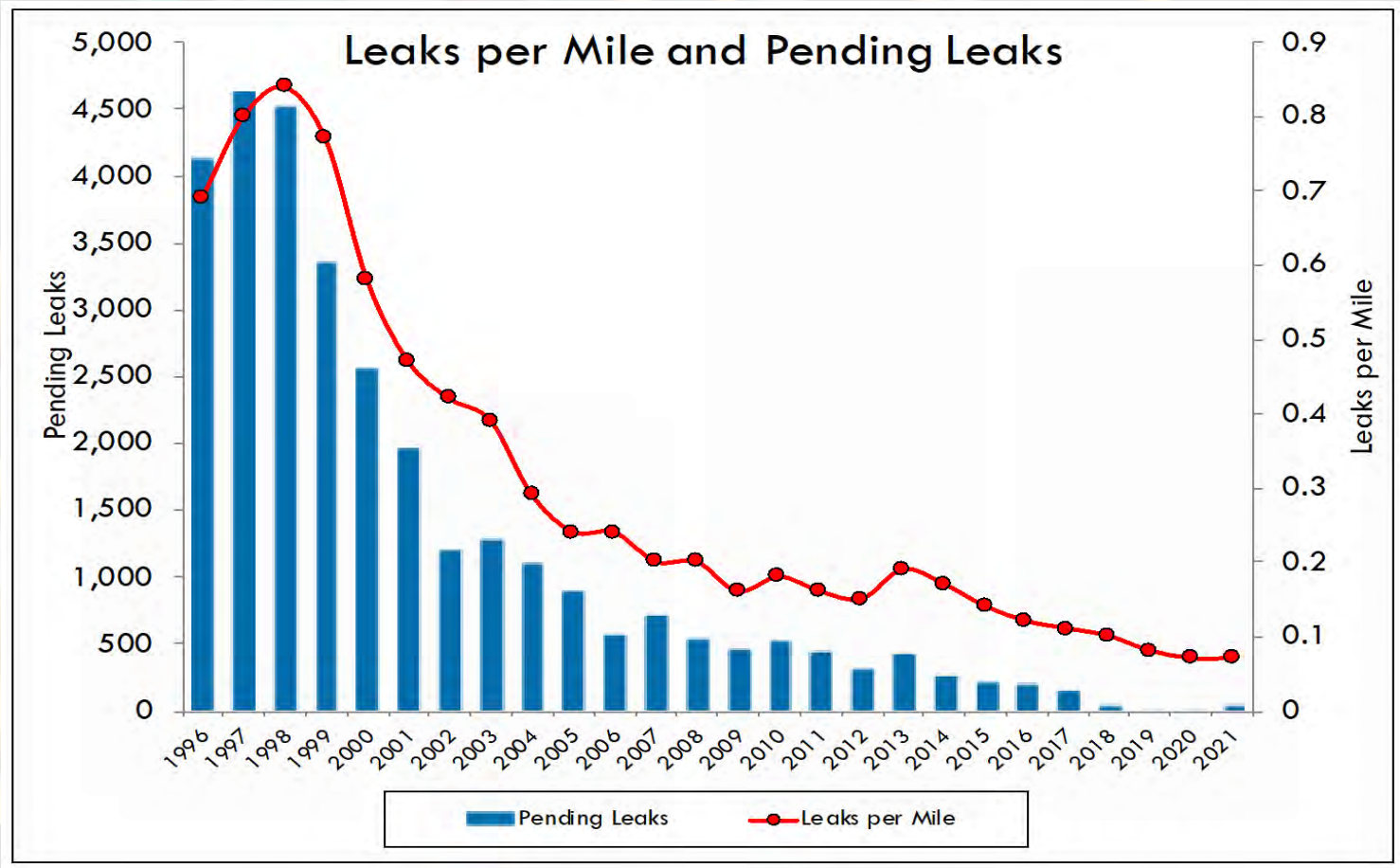
New Jersey Natural Gas

- Largest Subsidiary of New Jersey Resources (NJR)
- Founded in 1952
- Nearly 563,000 customers across five counties
- Over 7,500 miles of distribution and transmission pipeline
- J.D. Power Highest Customer Satisfaction with Residential Natural Gas Service in the East Among Large Utilities*, 6 years in a row

*For J.D. Power 2020 award information, visit jdpower.com/awards

Most Environmentally Sound Natural Gas System in the State*

- More than $2 Billion in System Investments in Last Decade
- Fewest leaks-per-mile of any natural gas utility in New Jersey
- Cut emissions by more than 900 metric tons since 2015
- Reduction of operational emissions in New Jersey **>50%** from 2006 levels



Investments to remove cast iron and bare steel drive leak reduction

New Jersey Resources

*As measured by leaks per mile

Investments to date position NJNG to deliver decarbonized molecules to our customers in the Clean Energy Future

New Jersey Resources

By the year 2050 …

… we believe NJNG will serve its customers with a carbon neutral fuel supply.

Zero Carbon Fuels: RNG

Landfill

Wastewater

Food Waste

Anaerobic Digester

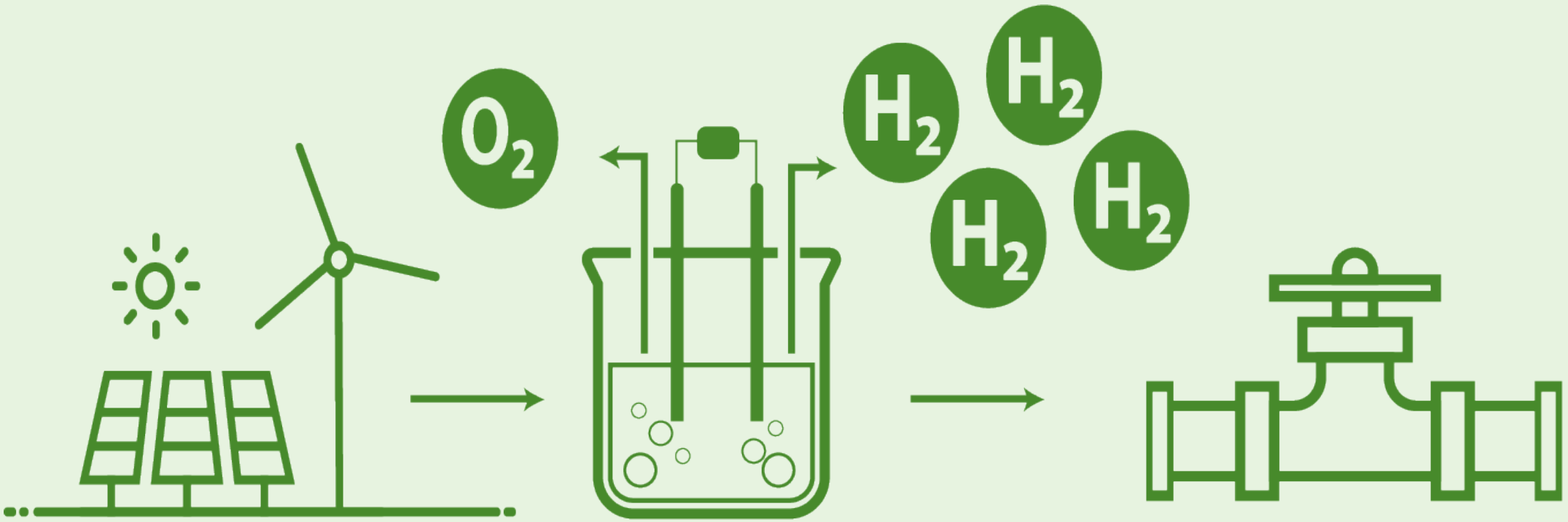
Biogas

Advanced Processing

RNG

New Jersey Resources

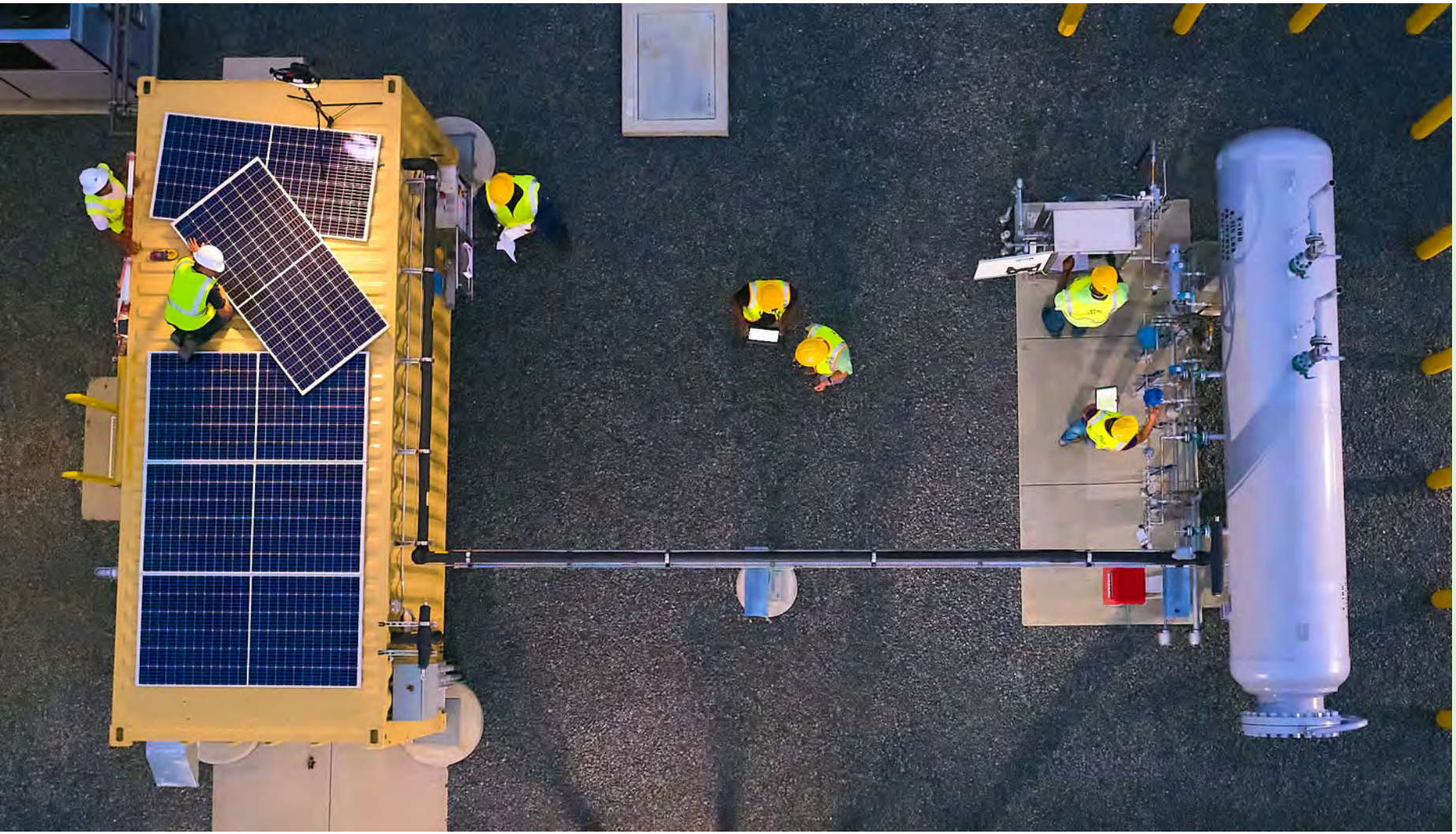
Zero Carbon Fuels: Green Hydrogen



Optimizing Renewable Resources

- New Jersey's energy goals call for a substantial increase in wind and solar renewable generation
  - 7,500 MW of offshore wind capacity by 2035
  - 14,000 MW of additional solar capacity by 2035
- Significant energy supply-demand imbalances and excess renewable power expected
- Excess power could be converted to hydrogen avoiding waste and benefitting customers

NJNG's Howell Green Hydrogen Project



The first project on the East Coast
to deliver
green hydrogen
through a utility distribution pipeline to customers' homes and businesses

A clean energy New Jersey **starts here**.

New Jersey Resources

Howell Green Hydrogen Project

Project Status

- Commercial operation reached in October 2021
- Entire project located within NJNG's Howell facility
- Converts renewable electricity on-site to zero-carbon hydrogen, blended into natural gas distribution system
- System expected to offset ~180 US tons of CO_2 per year

NJNG Howell LNG Facility

Electrolyzer will source solar power from a 416 kw DC array on site

Electrical current will split water molecules into hydrogen and oxygen

Hydrogen initially stored in onsite vessel before being blended into distribution system

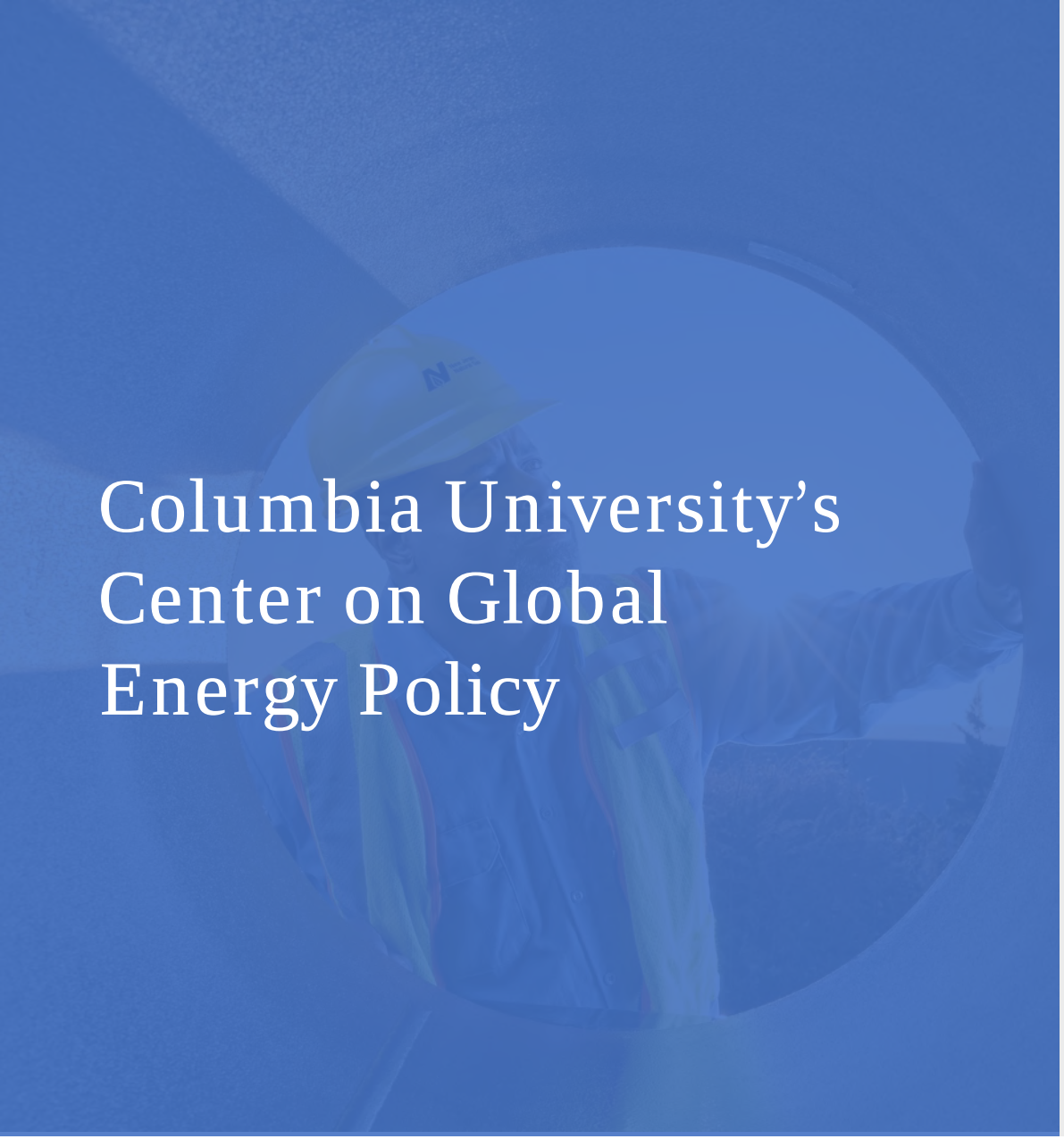
New Jersey Resources

A Growing Consensus…

ENERGY earthshots
U.S. DEPARTMENT OF ENERGY

- Bolster development and deployment of carbon-neutral fuels
- The Hydrogen Shot initiative seeks to cut the cost of hydrogen fuels
- Clean hydrogen fuels are a promising technology and may play a key role in decarbonizing fuel streams and the global supply chain

The infrastructure we have is an asset we should use, not discard.



Columbia University's Center on Global Energy Policy

"Retrofitting and otherwise improving the existing pipeline system are **not a choice between natural gas and electrification or between fossil fuels and zero-carbon fuels**.

Rather, these investments in **existing infrastructure can support a pathway toward wider storage and delivery of cleaner and increasingly low-carbon gases while lowering the overall cost of the [clean energy] transition** and ensuring reliability across the energy system."

Key Takeaways

- Prudent regulatory policy and investments have positioned NJNG's system to deliver decarbonized fuels
- RNG from landfills, food waste and wastewater facilities present real opportunities for New Jersey to leverage decarbonized fuels
- Green Hydrogen is here, and will grow in the future as more renewable generation sources become available
- Green Hydrogen deployed on existing gas systems offers a practical solution for large scale, long-duration renewable power storage
- These decarbonized fuels can be used for home heating/appliance use as well as for transportation

New Jersey Resources

Q&A
Panel Discussion

Case Studies: Decarbonized Gas Now

- Juan Corcino - Manhattan Beer
- Rick Dovey - Atlantic County Utility Authority
- Ricardo Hamdan - Hitachi Zosen Inova
- Chelsea Jenkins – Roush CleanTech

MANHATTAN BEER DISTRIBUTORS®

Fleet & Environmental Initiatives

At Manhattan Beer Distributors, we know that in order to effect change, we all must contribute. For this reason, we have continuously invested in minimizing our environmental footprint across several areas of focus.

Compressed Natural Gas:

We were the first company in the Northeast to convert a portion of our Diesel-powered fleet to Compressed Natural Gas, or CNG /RNG, trucks. Continuing over two decades since the onset of the program, Manhattan Beer Distributors has expanded this fleet, currently operating over 200 CNG delivery trucks as well as 3 private on-site CNG fueling stations. Our communities, customers, and employees can all breathe easier as a result of these low-emission vehicles.

Over 200 route delivery Trucks / Tractors

Wyandanch CNG Station:

CNG Benefits:

Great for the environment

Incentives available to reduce the incremental cost of new vehicle purchases

CNG Barriers:

High Cost of CNG Station

Cost of new CNG TRUCKS

Our fleet strategy is focused on safety, the environment, and our aging equipment.

Key Recent Developments in Our Fleet Program

- 3 new CNG stations in Bronx, Wyandanch, and Suffern Facilities.
- 6 type-3 charging stations for electric trucks
- 60 CNG tractors, and 5 Electric Tractors. These will replace 78 Diesel units.
- We continue to expand the role of CNG and Electric in our fleet, 53% CNG & Electric vs. 49% Diesel
- We are planning fleet purchases of approx. 35 trucks per year after 2021

Atlantic City Utility Authority

Rick Dovey

President

Intersection Between RNG and H2. Case Studies Decarbonizing Gas in NJ

Ricardo Hamdan

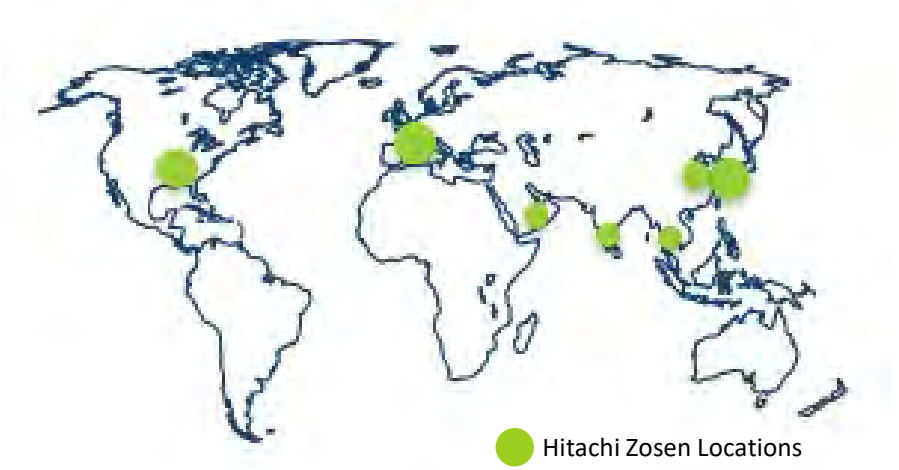
Hitachi Zosen Inova

Who is HZI?

Hitachi Zosen Inova
Global Leader in Energy from Waste

Hitachi Zosen Corporation (Hitz)

- Founded in 1881, 9500 employees
- Osaka, Japan based industrial and engineering company focused on the waste and environmental business sectors.
- Revenue ~3.7 billion USD



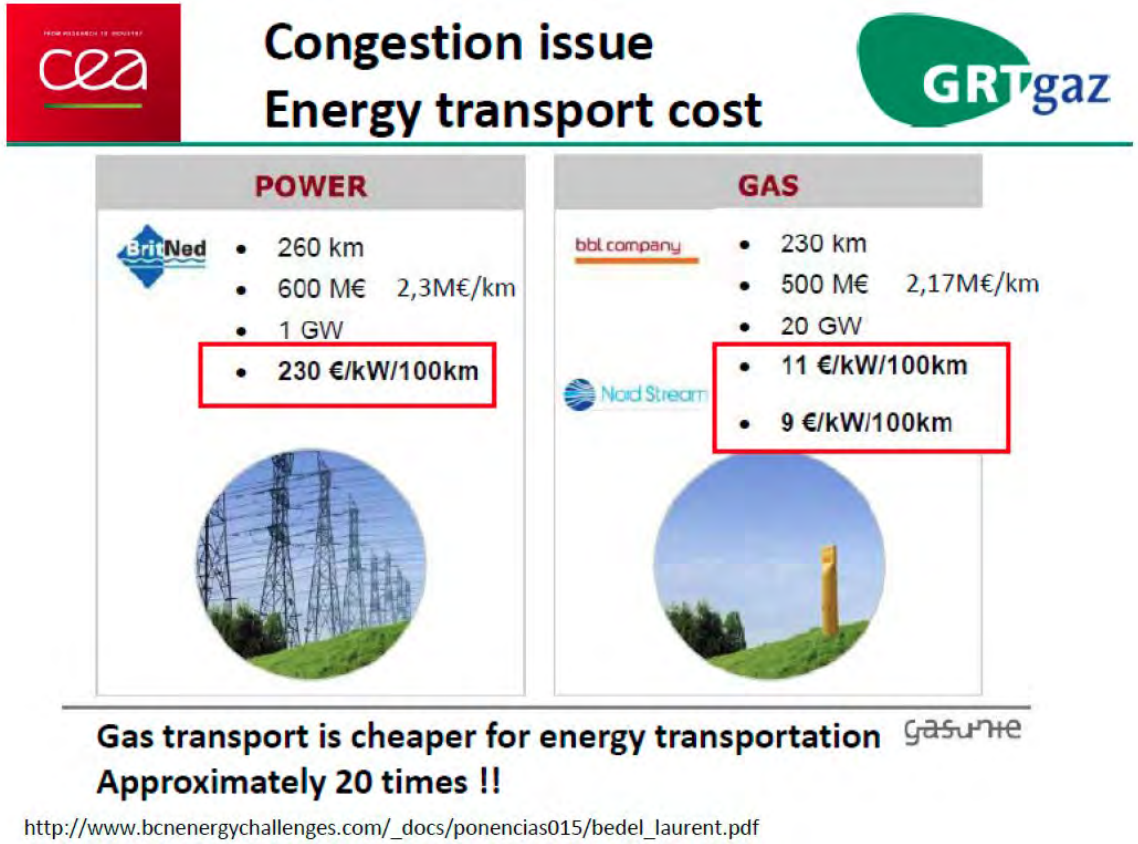
Hitachi Zosen Inova (HZI)

- 100% wholly owned subsidiary of Hitachi Zosen
- HZI is the global market leader in energy from waste solutions.
- HZI is headquartered in Zurich, Switzerland with offices in Germany, Italy, Slovakia, Sweden, China, Australia, USA, Canada, etc.
- HZI with proprietary products span incineration, anaerobic digestion, renewable natural gas processing, and moving quickly into methanation, hydrogen and CO2
- Over 500 reference projects worldwide
- Dedicated R&D continuously improving and expanding

Hitachi Zosen Inova North America

Decarbonizing Infrastructure

Keyword is: TRANSITION



http://www.bcnenergychallenges.com/_docs/ponencias015/bedel_laurent.pdf

- We can't electrify everything.
- RNG as a gateway fuel
- Have a plan. Decarbonize as infrastructure builds up, but think long term.

Building RNG + H2 compatible infrastructure

- **RNG Projects are versatile.**
  - A biogas plant today with:
    - Gas Upgrading + Electrolysis + Methanation = CH4 in TODAY's pipeline.

    can tomorrow be a plant with:
    - Gas Upgrading + Electrolysis + SMR = H2 in TOMORROW's pipeline.
    - You keep the Gas Upgrading + Electrolysis assets.

- **RNG / H2 as an industry decarbonizer.**
  - RNG and Hydrogen can be used to decarbonize heavy industry such as Cement, Steel, Ethanol.
  - Utilities are currently in the process of allowing 10% blends H2 in pipelines, improving the pipeline quality which will mitigate and avoid leakage.
  - RNG from CO2 Capture mixed with H2 generation at landfills can extend its life while the industry transitions to process organics separately.

Types of Low Carbon H2

Blue Hydrogen

- Hydrogen derived from splitting Natural Gas using:
- *Steam Methane Reformation* **+** *Carbon Capture and Storage or Utilization.*
- This process produces H2 CO2 and O2 as a byproduct.
- Green premium is not as high.

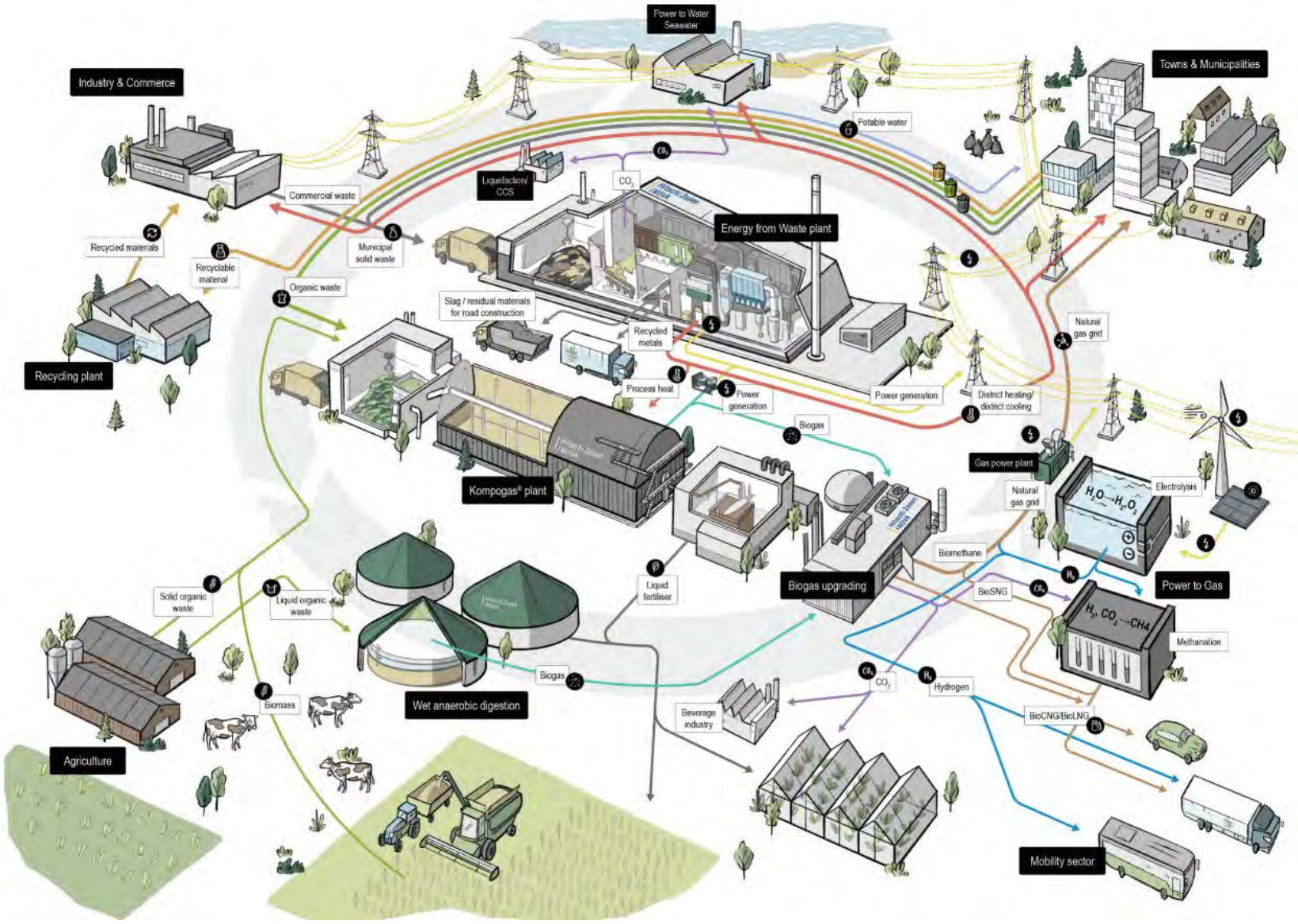
Green Hydrogen

- Hydrogen derived from the electrolysis of renewable energy:
- *Power + Water with Caustic Solution = H2 and O2*
- This process produces zero carbon H2.
- Green premium is currently high.

Turqouise Hydrogen

- Hydrogen derived from the HT pyrolysis of biomass
- *Biomass + Water + High heat (800 C). Offgas is reused.*
- This process produces zero carbon H2 and biochar.
- Green premium is not as high.

HZI view of the Plant of the Future: the Urban Waste



Decarbonisation

Transportation using RNG

Ontario's first carbon-negative bus hits the road

Published: March 04, 2021

Case Studies

San Luis Obispo, USA
AD + Turquoise H2

Client	**Kompogas SLO LLC**
Start-up	**2018**
Technology	
Waste types	SSO - Green waste, food waste
Digester	PF1800 steel digester
Biogas utilization	Electricity grid injection
Technical Data	
Waste throughput	82 t/day - 30,000 t/a
Biogas production	2,900,000 Nm^3/a
	16,200,000 kWh/a
Electrical power production	6,200,000 kWh/a
Compost production	12,000 t/a
Liquid fertilizer production	1,600 t/a

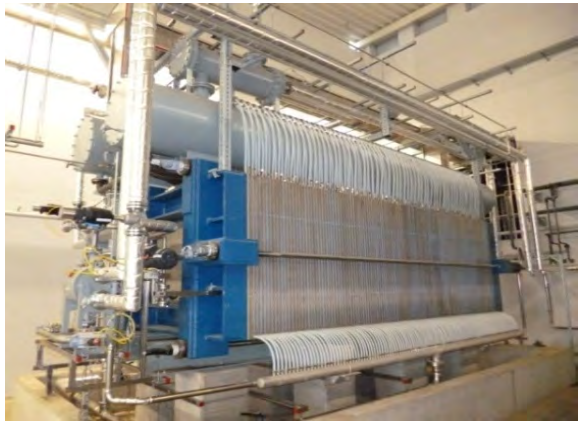
- First Kompogas® plant in the USA
- Design Build Finance Own and Operate (DBFOO) for 20 years by HZI's subsidiary Kompogas SLO LLC
- Biogas utilization in combined heat and power unit (CHP), covering power needs of more than 600 US households
- The plant contributes to California's goal to divert food waste from landfills and hence reduce greenhouse gas emissions
- Next phase is the transformation of the post digestion digestate into Turquoise Hydrogen

Power-to-SNG / RNG / Carbon Capture Werlte, Germany

Plant Capacity	**6.3 MWe + Methanation**
Production	**330 nm³/h CH4**
Operation	**2011**

Power-to-SNG / RNG / Carbon Capture Werlte, Germany

Electrolyser hall



One of the three 2MW$_{el}$ elecktrolyser

Methanation Reactor

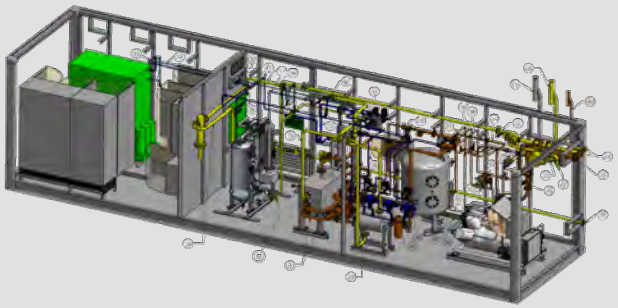
Power-to-SNG
Nagaoka, Inpex-1, Japan

Plant Capacity	**160 kW**
Production	**8 nm³/h CH4**
Operation	**2019**

Power-to-SNG
Nagaoka, Inpex-1, Japan

Methanation

Compact methanation Plant for small capacity

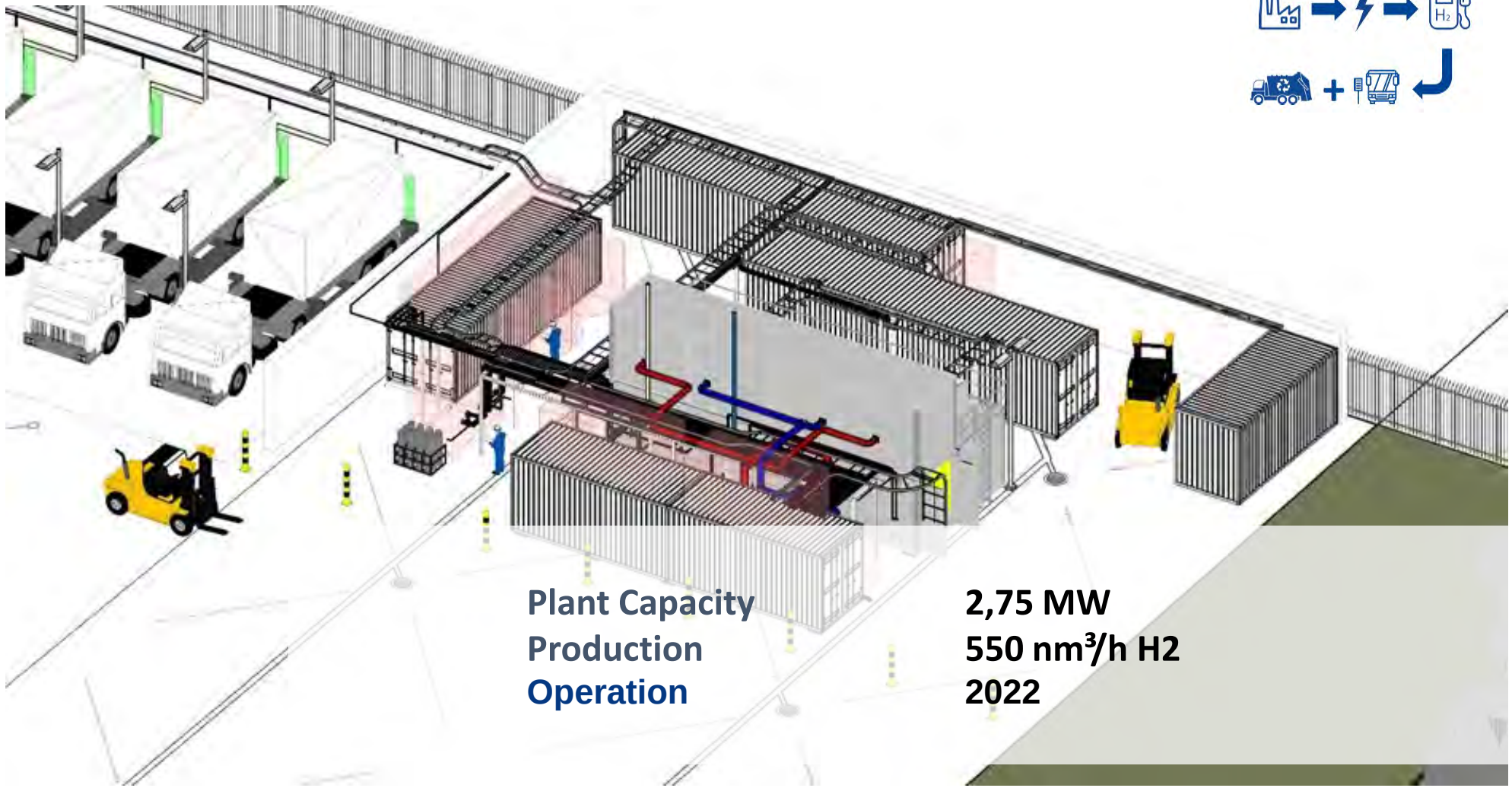


Turnkey plant for reference project

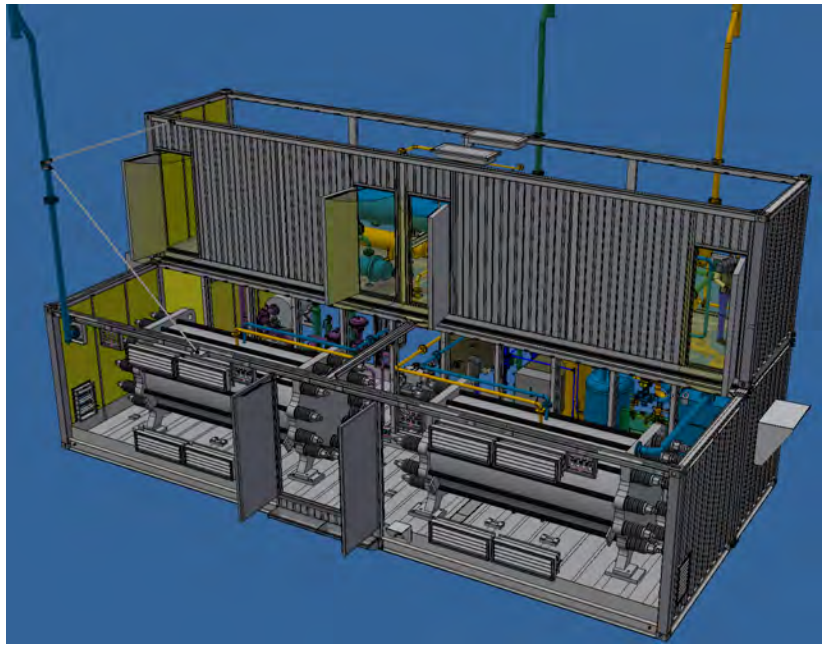
- ✓ Proof of the in-house Power-to-SNG concept: electrolyser and advanced methanation reactor technology.
- ✓ Carbon dioxide from an industrial off-gas to reduce CO2 emissions
- ✓ Production of high-grade SNG (>= 96%) with a membrane gas treatment process including recycling
- ✓ Proof of performance on a small scale (8 Nm^3/h SNG), but reactor scalability towards multi-MW applications
- ✓ Fully automatic operation of the plant
- ✓ Use of reaction heat to generate high pressure steam >= 35 barg for consumption elsewhere in the plant
- ✓ Conformity with common international codes & standards: ASME, ATEX

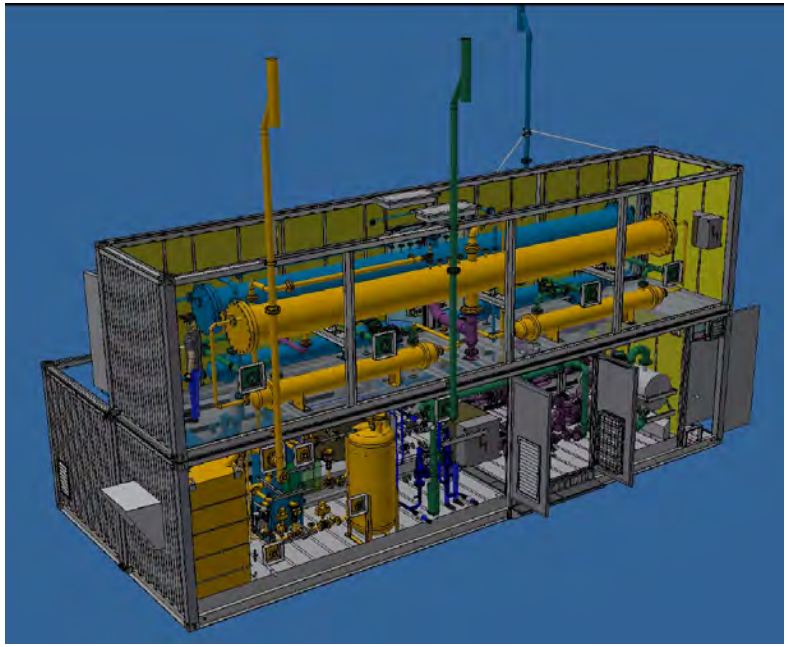
2020 : Large scale methanation reactor design (8MW, 420 Nm3/h): Inpex-2

Power-to-Hydrogen
Buchs, Switzerland



Power-to-Hydrogen
Buchs, Switzerland





Plant Capacity
Production
Operation

2,75 MW
550 nm³/h H2
2022

Power-to-Hydrogen Buchs, Switzerland

USPs of PtH2 solution

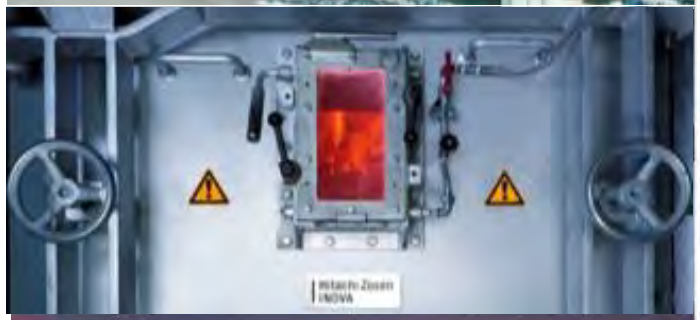
- ✓ Containerized system and full turnkey modular design for outdoor installation
- ✓ Superior conversion efficiency for pressurised system minimises OPEX
- ✓ Lowest capital cost for electrolyser components
- ✓ Very good coverage of all dynamic operation requirements (delivering ancillary services to the grid)
- ✓ Scalability to multi-MW utility-scale capacity

Data Sheet Electrolyser 50 kg/h

Quality H2	**ISO 14687 SAE 2719**	
Nominal load	**MW_{el}**	**2.75**
Load range	**%**	**20-110**
Dynamic	**$\%_{Nominal}$/sec**	**> 0.5**
H_2 production @15 barG	**Nm^3/h**	**550**
Efficiency at full load (without compression)	**$kWh_{el}/Nm^3\ H_2$ $kWh_{el}/kg\ H_2$**	**4,8 54**
Footprint area (turn-key)	**M^2**	**30 x 15**

Waste is our Energy

Hitachi Zosen INOVA



Waste is our Energy.

Engineering is our Business.

Sustainable Solutions are our Mission.

Ricardo Hamdan
Sales Manager. Renewable Gas
+1-647-336-4020
Ricardo.Hamdan@hz-inova.com

Welcome

Chelsea Jenkins
Vice President, Government and Industry Relations

8/5/2021

ROUSH® CLEANTECH

ROUSH AT A GLANCE

Privately Held

Michigan-based

Founded in 1976

5,000+ Employees

3 MILLION sq. ft. office / development space

50 YEARS of product development expertise

PRIMARY ACTIVITIES

Design | Engineering | Prototyping | Testing | Manufacturing

MARKETS & CUSTOMERS WE SERVE

MOBILITY

Ford
FCA
GM
Argo.ai
GAC
Aptiv
Rivian
Toyota
Google/Waymo
Honda
Hyundai
Isuzu
Volkswagen
Nissan
Bluebird
BMW

DEFENSE

Navistar Defense
BAE Systems
AM General
SAIC
Textron
FAAC
US Army/TARDEC
OskoshDefense
Hardwire
Astradyne

ENTERTAINMENT

Disney Parks, Experience & Products
Universal Parks & Resorts
SeaWorld Parks & Entertainment
The Henry Ford Entertainment Suppliers

AEROSPACE

Bell Helicopter
Boeing
Pratt & Whitney
Sikorsky
United Launch Alliance

ROUSH IN THE ELECTRIC VEHICLE INDUSTRY

1998 — Ford Ranger EV Prototyping

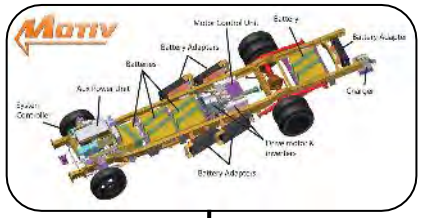
1999 — 1st Hybrid Transmission Prototype Build & Test

2005 — Ford Escape HEV Prototyping

2008 — Fisker Design Engineering

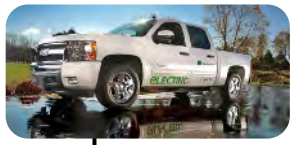
2009 — Roush Electric Vehicle

2011 — Motiv BEV Assembly



2011 — Blink Charger Assembly

2012 — VIA Motors Design & Prototyping



2014 — Google Firefly Design & Production

2014 — Cummins AEOS Class 7 EV Demo

2017 — CONFIDENTIAL

Series Hybrid Commercial Truck

2017 — CONFIDENTIAL

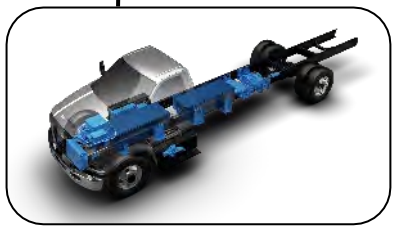
Mobile High Voltage Charging Vehicle

2018 — Farmwise Agribot

2018 — Canoo

2019 — Nuro AI Delivery Bot

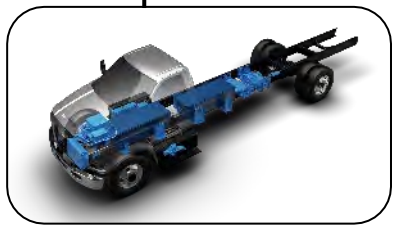
2020 — Roush Cleantech F650 BEV



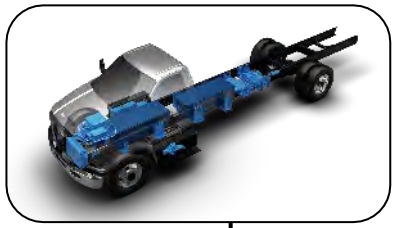
2021 — CARB UPS Hydrogen Fuel Cell Electric Vehicle

2022 — MBRDNA Battery Testing

2023 — ROUSH Charged F650 BEV2.0



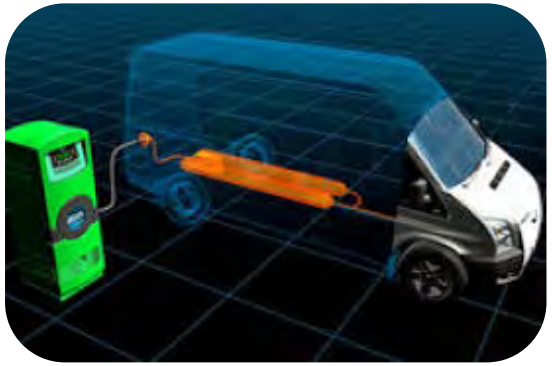
2024 — ROUSH CleanTech F750 BEV

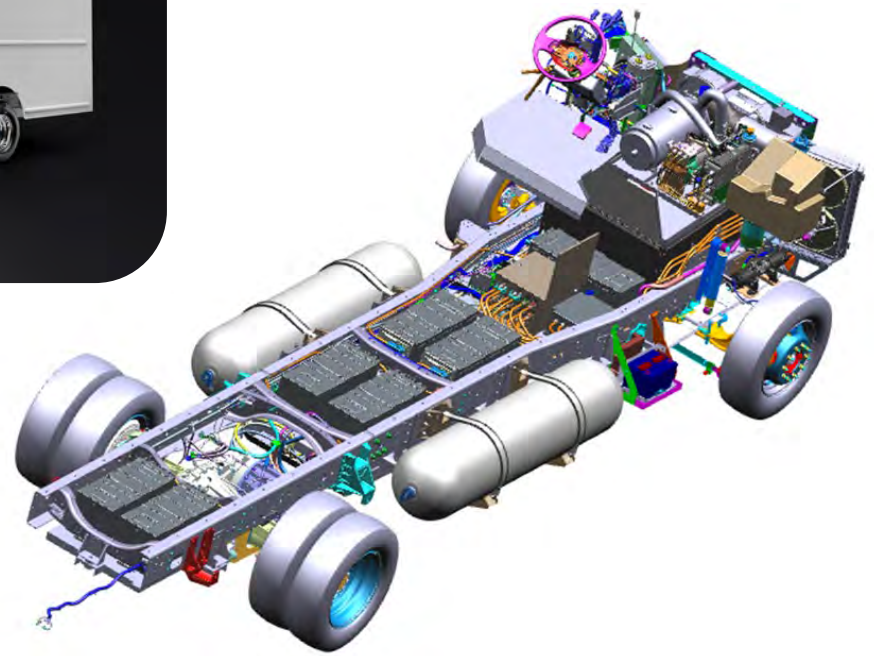


HFCEV

Entire Vehicle Design, Development, Build Capability …

- **Roush Transit** Bi Fuel Development Vehicle
- **OEM Hydrogen Fuel Cell** Technology Demonstrator Vehicle Fleet
  - •Compact Sedan, Crossover, SUV
- **Ford 999** Hydrogen Land Speed Record Vehicle
  - •Ford Fusion Hydrogen Fuel Cell
- **UPS Hydrogen Fuel Cell** BEV F59 Delivery Fleet





Current Products

School Buses

Blue Bird Vision
Propane, CNG

Micro Bird G5
Propane

Chassis Cabs

F-650 / F-750
Propane, Electric

F-450 / F-550
Propane

Stripped Chassis/Cutaways

F-59 / F-53
Propane

E-350 / E-450
Propane

OVER

40,000

VEHICLES ON THE ROAD

OVER

1 Billion

MILES ACCUMULATED

OVER

2,500

FLEETS

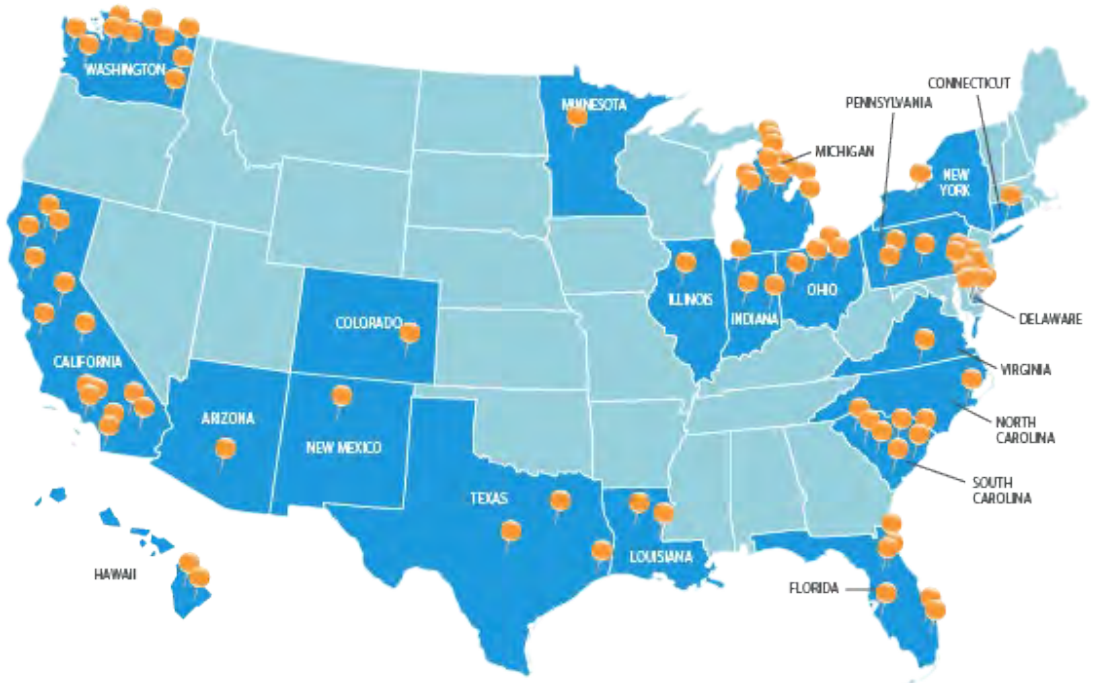
BEV Class 6 Offering

Ford F-650 – 2023 full production

- Prototype Production 2017
- Demonstrator units 2019
- Range: 120 miles (Maximum Payload)
- Payload: 14,500lbs (8500 w/upfit)
- Gross Vehicle Weight: 26,000lbs
- Charging: 19.2Kw / 50Kw
- Proterra 165KwH HV Battery
- eAxle
- Wheelbase: 194” to 260”

Have You Seen Any of These On the Road?

Propane Paratransit Deployments



More than 1,500 propane paratransit buses

1. **DELAWARE TRANSIT CORPORATION**
   NEW CASTLE, DELAWARE

2. **BROWARD COUNTY TRANSIT**
   FORT LAUDERDALE, FLORIDA

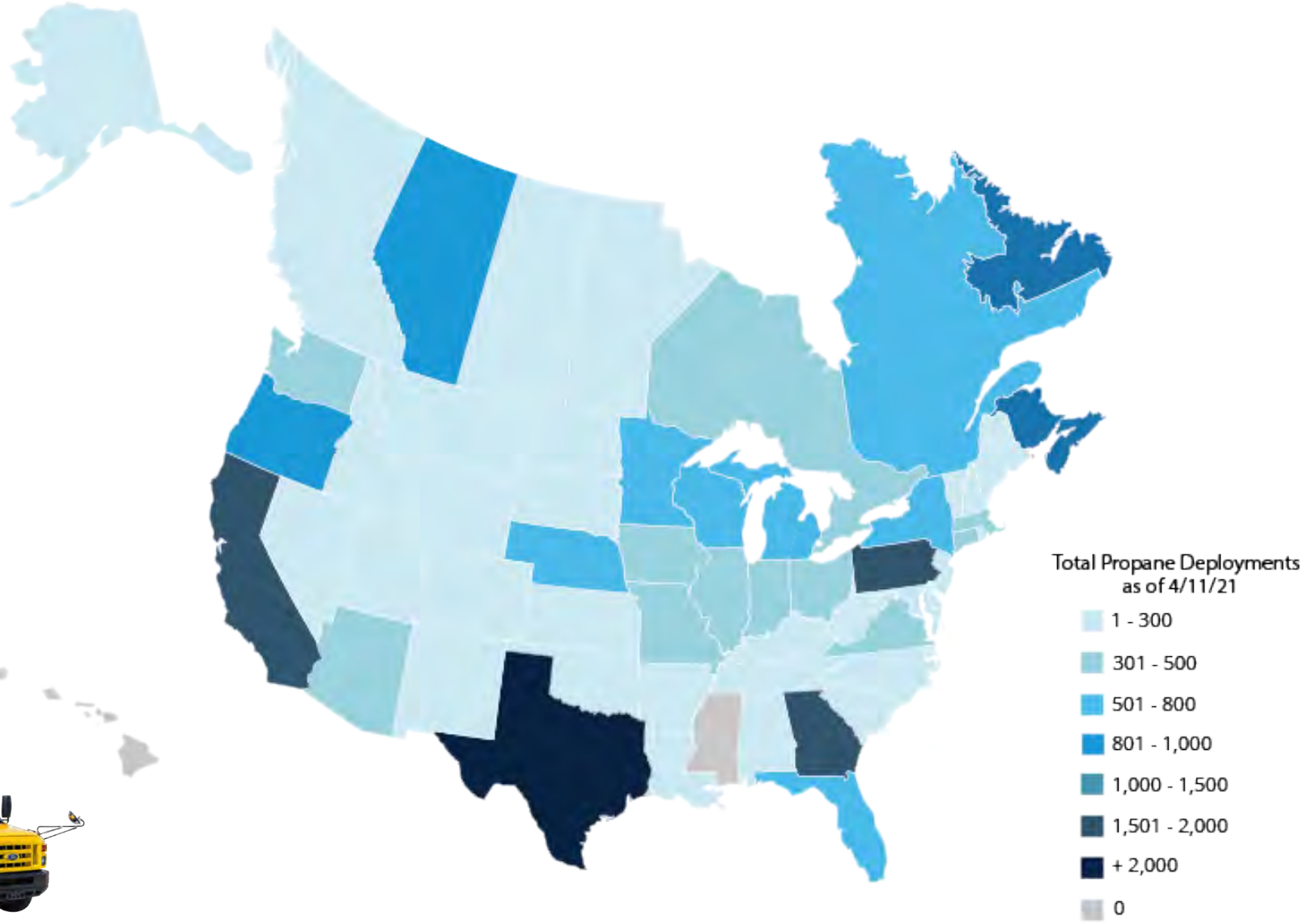
3. **FLINT MASS TRANSPORTATION AUTHORITY**
   FLINT, MICHIGAN

4. **SAN DIEGO METROPOLITAN TRANSIT**
   SAN DIEGO, CALIFORNIA

5. **SUBURBAN MOBILITY AUTHORITY FOR REGIONAL TRANSPORTATION**
   DETROIT, MICHIGAN

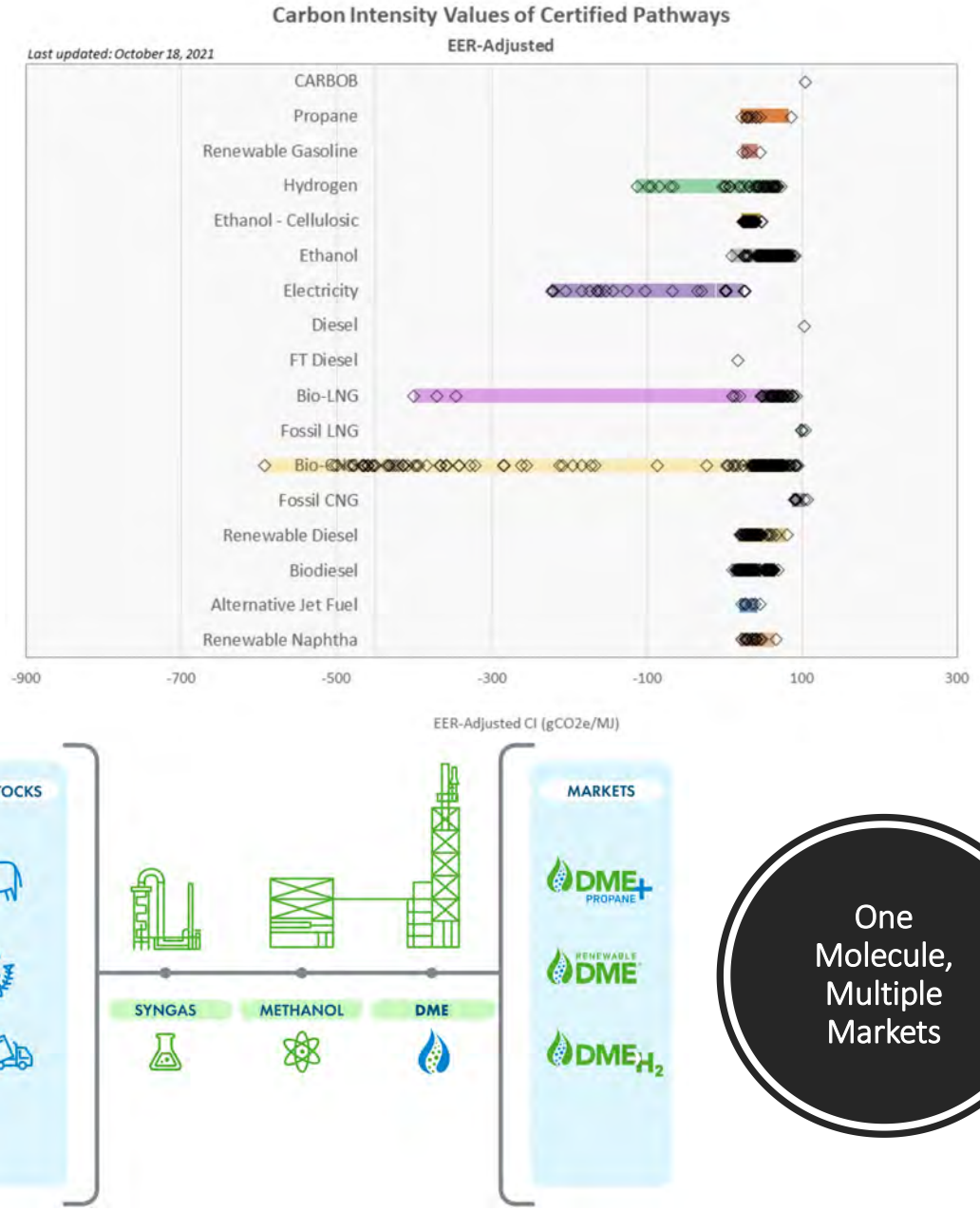
Propane School Bus Deployments

More than 17,700 propane school buses in North America



Decarbonizing Propane

Renewable Propane, in commercial practice, is identical to the fossil counterpart. That is, the chemical structure and physical properties are the same – they just come from different sources.



One Molecule, Multiple Markets

Decarbonizing Propane

1. REG currently producing RLPG in US
2. Oberon Fuels producing renewable DME
3. Neste producing RLPG in Europe
4. Partnerships announced to produce rDME
    1. SHV and UGI
    2. SHV and KEW
5. Investment globally and in US to increase supply of rLPG and rDME growing

Highlights

- Globally, projects underway evaluating rDME in residential, commercial, off-road, and on-road applications
- CA vehicle fleet currently testing rDME+LPG blends
- FPT is researching DME in large displacement engines
- DOE Vehicle Technologies Office announced nearly $4.4M in research into DME + LPG fuel blends in engines
- DOE Technology Commercialization awarded $1.5M to Los Alamos National Lab to scale up DME to hydrogen reforming technologies

Los Alamos National Laboratory and Oberon Fuels Receive Department of Energy Funding to Produce Renewable Hydrogen from Renewable DME (rDME)

24 JUN 2021

Project will develop novel pathway to reducing carbon content of global hydrogen supply

Converting renewable DME into hydrogen will solve vexing issues related to hydrogen production, transport and storage and open up new feedstocks for cost-effective renewable hydrogen production

SAN DIEGO (June 24, 2021) – A public-private partnership between Los Alamos National Laboratory (the Laboratory) and Southern California-based Oberon Fuels has secured funding from the U.S. Department of Energy (DOE). The Laboratory/Oberon project is expected to scale-up steam reforming technology to produce renewable hydrogen (rH2) from renewable dimethyl ether (rDME), an innovative approach to increasing the global renewable hydrogen supply.

The effort is funded by DOE's Technology Commercialization Fund, which supports mature, promising energy technologies with the potential for high impact and is also part of DOE's "H2@Scale" initiative to accelerate development of a hydrogen economy by funding advanced-technology research, development and demonstration (RD&D) with industrial partners.

Renewable DME has the potential to overcome the two largest barriers to widespread hydrogen adoption: the lack of cost-competitive, sustainable production and lack of energy-dense storage and transport.

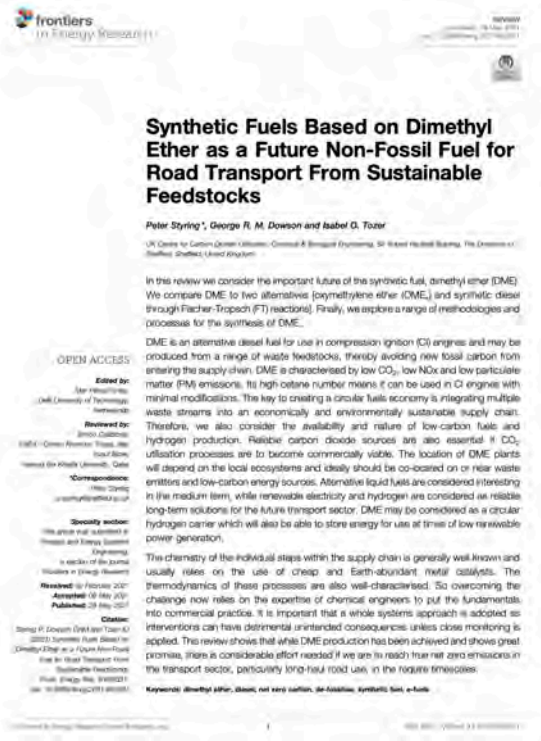
DME is a hydrogen-rich molecule that can be produced from waste and/or renewable resources using Oberon's modular production technology. Because DME handles like propane/liquefied petroleum gas (LPG), it requires minimal modifications to the existing global LPG distribution network and leverages the expertise of its existing workforce. This project will produce the final step – technology that can convert rDME into rH2 fuel at the point of use.

"Our novel approach to generating hydrogen flips the current model on its head," said Rebecca Boudreaux, Ph.D., President and CEO of Oberon Fuels. "We are producing a hydrogen-rich molecule, moving it using existing, low-cost infrastructure, and converting it to hydrogen fuel on demand. We are thrilled to partner with Los Alamos National Laboratory and the Department

Fiscal Year 2021 Low Greenhouse Gas (GHG) Vehicle Technologies Research, Development, Demonstration and Deployment

FOA # DE-FOA-0002475

AOI 6 - Dimethyl Ether and Propane Engine Enabling Technologies			
University of Wisconsin-Madison	Madison, WI	High-Efficiency Mixing Controlled Compression Ignition Combustion of Propane DME Blends	$2,373,453
WM International Engineering L.L.C.	Darrien, IL	High Pressure Fast Response Direct Injection System for Liquified Gas Fuels Use in Light-Duty Engines	$1,994,690



frontiers in Energy Research

Synthetic Fuels Based on Dimethyl Ether as a Future Non-Fossil Fuel for Road Transport From Sustainable Feedstocks

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OPEN ACCESS

In this review we consider the important future of this synthetic fuel, dimethyl ether (DME). We compare DME to two alternatives (oxymethylene ether (OME$_n$) and synthetic diesel through Fischer-Tropsch (FT) reactions). Finally, we explore a range of methodologies and processes for the synthesis of DME.

DME is an alternative diesel fuel for use in compression ignition (CI) engines and may be produced from a range of waste feedstocks, thereby avoiding new fossil carbon from entering the supply chain. DME is characterised by low CO_2, low NOx and low particulate matter (PM) emissions. Its high cetane number means it can be used in CI engines with minimal modifications. The key to creating a circular fuels economy is integrating multiple waste streams into an economically and environmentally sustainable supply chain. Therefore, we also consider the availability and nature of low-carbon fuels and hydrogen production. Reliable carbon dioxide sources are also essential if CO_2 utilisation processes are to become commercially viable. The location of DME plants will depend on the local ecosystems and ideally should be co-located on or near waste emitters and low-carbon energy sources. Alternative liquid fuels are considered interesting in the medium term, while renewable electricity and hydrogen are considered as reliable long-term solutions for the future transport sector. DME may be considered as a circular hydrogen carrier which will also be able to store energy for use at times of low renewable power generation.

The chemistry of the individual steps within the supply chain is generally well known and usually relies on the use of cheap and Earth-abundant metal catalysts. The thermodynamics of these processes are also well-characterised. So overcoming the challenge now relies on the expertise of chemical engineers to put the fundamentals into commercial practice. It is important that a whole systems approach is adopted as interventions can have detrimental unintended consequences unless close monitoring is applied. This review shows that while DME production has been achieved and shows great promise, there is considerable effort needed if we are to reach true net zero emissions in the transport sector, particularly long-haul road use, in the require timescales.

THANK YOU

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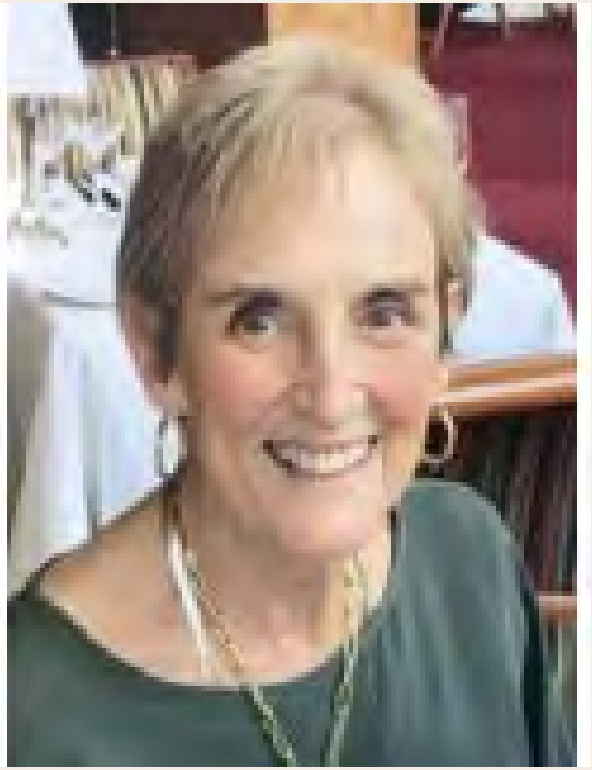
Closing Comments



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