



# Achieving Low Risk, Affordable Decarbonization of the U.S. Locomotive Fleet to Zero Emissions Using a Diesel-RNG Dual Fuel “No Tender” Solution

PRESENTED BY:

Scott Myers  
CEO & President



## 2024 TTC CONFERENCE



ACCELERATING THE PACE TO  
**TOTALZERO**



# 11 Years of Advancing Alternative Fuel Technology in Locomotives

- OptiFuel, a small business, is 100% focused on **zero emission** switcher and line haul locomotives
- OptiFuel locomotives are engineered to achieve FRA concurrence for alternative fuel locomotives
- Projects: Diesel-CNG Dual Fuel locomotives (IHB), Hydrogen Hybrid switchers (SNR), and DOE **5000 hp Diesel-RNG Dual Fuel Hybrid line haul locomotive**, set to undergo testing at TTC from 2025 to 2026, aiming for FRA concurrence by 2027
- Only company to develop and install CNG refueling station for rail, integrated with diesel at IHB Railroad



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# OptiFuel's Successful Diesel-CNG Dual Fuel Locomotive Program at the Indiana Harbor Belt (IHB) Railroad

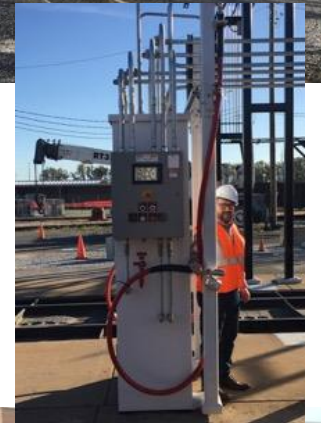
OptiFuel built four dual fuel locomotives that have successfully been in service for over five years. These locomotives have achieved both FRA concurrence and EPA approval, and they are refueled onsite at a dedicated CNG refueling.

- **Converted CAT C18 Tier 4 Interim engines (750 hp) to dual fuel mode, achieving EPA certification**
- **First company to obtain FRA concurrence with CNG storage onboard the freight locomotive**
- **Integrated CNG/RNG refueling equipment into existing diesel refueling islands in just 9 months**

Go to

<https://optifuelsystems.com/media>

to see a video of the refueling of the CNG locomotive at the IHB Railroad



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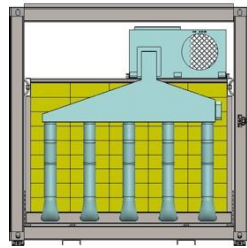
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# OptiFuel Has a Current Contract With Sierra Northern Railway (SNR) to Provide the Fuel Cell, Hydrogen Storage, and Battery Modules for the CEC Hydrogen Switcher Locomotive Program

- SNR/GTI has a contract with the California Energy Commission (CEC) to develop and test a 100% powered Hydrogen-Battery switcher freight locomotive
- Designed to operate for 10 years in switcher operations



Lithium Battery QD Module



Hydrogen Fuel Cell QD Module



H<sub>2</sub> On-deck Storage QD Module



**Completed in 1 Hour and 45 Minutes:**

## **Installation of Battery, Fuel Cell, Hydrogen Storage, and Cooling Modules on the Sierra Northern Railway Hydrogen Switcher Locomotive**

OptiFuel's Use of Modular Engineering and ISO-Locks Ensures Exceptional Speed, Value, and Consistency for Customers



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# The U.S. Locomotive Fleet Emits 652,000 Short Tons of NOx, 15,845 Tons of PM, and 43 Million Metric Tons (MMT) of CO2eq. Annually

As of September 2016, there are over 1000 U.S. railyards located in densely populated, urban areas classified by the EPA as “nonattainment” areas for particulate matter and ozone

- Over 119 million people (nearly 40% of the U.S. population) living in these nonattainment areas are experiencing acute and chronic adverse health outcomes, including exacerbation of respiratory and cardiovascular disease
- **North American freight locomotive fleet FY2021 statistics:**
  - At the end of 2021, the locomotive fleet totaled 37,988 and the average age is 29.2 years old
- **US Line Haul Locomotive Fleet Average Emissions:**
  - **NOx 5.5 g/bhp-hp, PM 0.2 g/bhp-hp, GHG Carbon Intensity 105**

Fleet by Horsepower (hp)		
Horsepower Range	% of Total Fleet	# of Locomotives
<2000 hp	11%	4,179
2000 hp – 2999 hp	13%	4,938
3000 hp – 3999 hp	20%	7,598
>3999 hp	56%	21,272

Fleet by Use and Configuration				
Type	Axle	HP	% of Total Fleet	# of Locomotives
Switcher	4-axle	<2500 hp	23.5%	8,927
Road	4-axle	>2500 hp	9%	3,419
Road	6-axle	>2500 hp	67.5%	25,642
Fuel Capacity >4,500 gallons			57%	21,272



# The Importance of Recognizing and Differentiating Between the Two Types of Emissions: Criteria Pollutants vs Greenhouse Gases

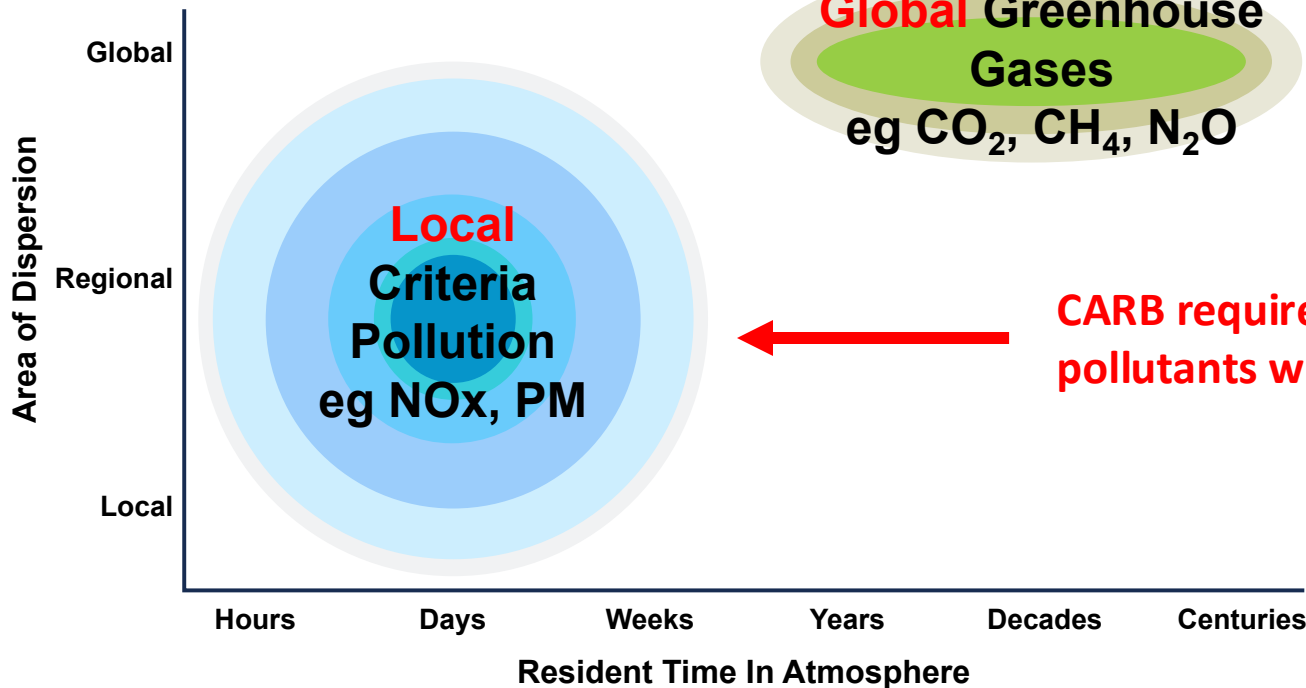
**LOCAL** Criteria pollutants (emissions) that create smog and ozone causing negative health effects are:

- **NOx** - Nitrous Oxides
- **PM** - Particulate Matter
- **CO** - Carbon Monoxide
- **NMHC** – Non-Methane Hydro-Carbons

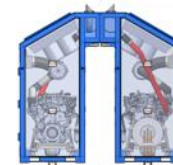
**Class 1 SBTi Targets are based on Greenhouse Gas (GHG) emissions, which significantly impact climate change**



**Solution:** Select or blend with clean fuels to reduce GHG emissions



**CARB requirements are based on NOx and PM emissions, criteria pollutants which negatively affect public health**

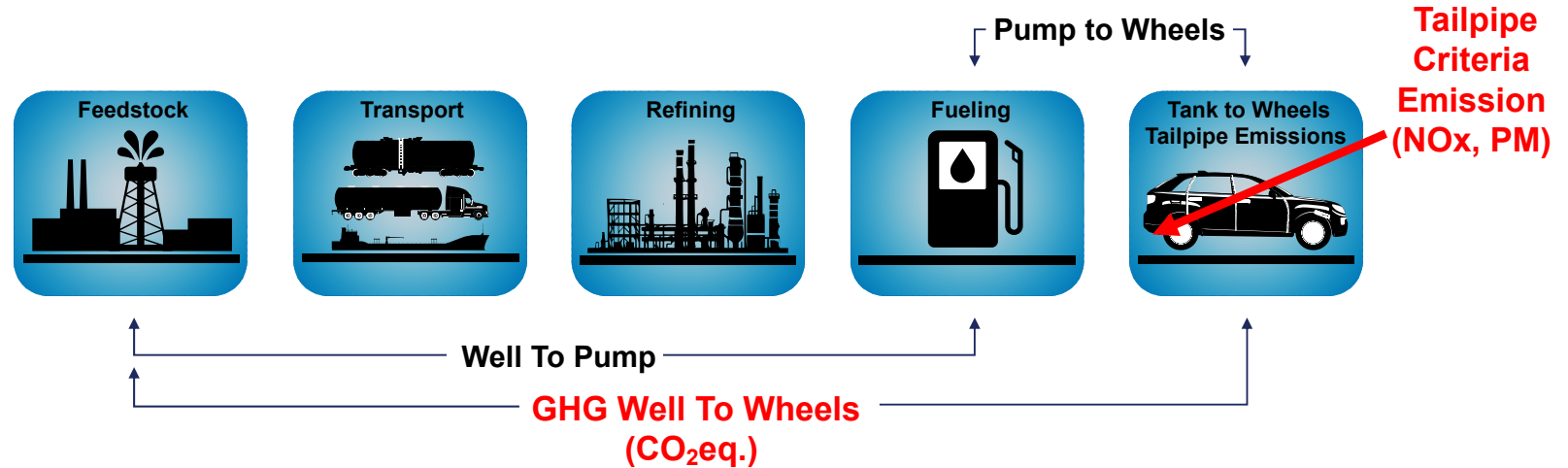


**Solution:** Implement modern power system technology to effectively eliminate these harmful emissions

# To Avoid CARB Fines and Achieve SBTi Targets, It's Essential for Solutions to Eliminate Criteria (Tailpipe) and Well-to-Wheel GHG Emissions

- OptiFuel's solutions are focused on eliminating Well-to-Wheel and Tailpipe emissions at the same time
- OptiFuel's first-generation dual fuel locomotive power system for the IHB railroad's locomotives integrated a dual fuel system into CAT C18 diesel engines to reduced GHG emissions and achieved NOx and PM reductions by blending diesel with a cleaner fuel, CNG, to achieve Tier 4
- To meet SBTi requirements for reducing or eliminating GHG emissions, it became essential to incorporate renewable fuels with NEGATIVE Carbon Intensity like RNG blended with diesel
- Recent advancements in diesel engine technology and after-treatment systems have enabled the development of clean diesel engines that can achieve near-zero NOx and PM emissions. Consequently, Diesel-RNG dual fuel systems have transitioned from being a distant possibility to a practical off-the-shelf solution, making them an ideal, low risk, affordable choice for decarbonizing locomotives for the next 30 years

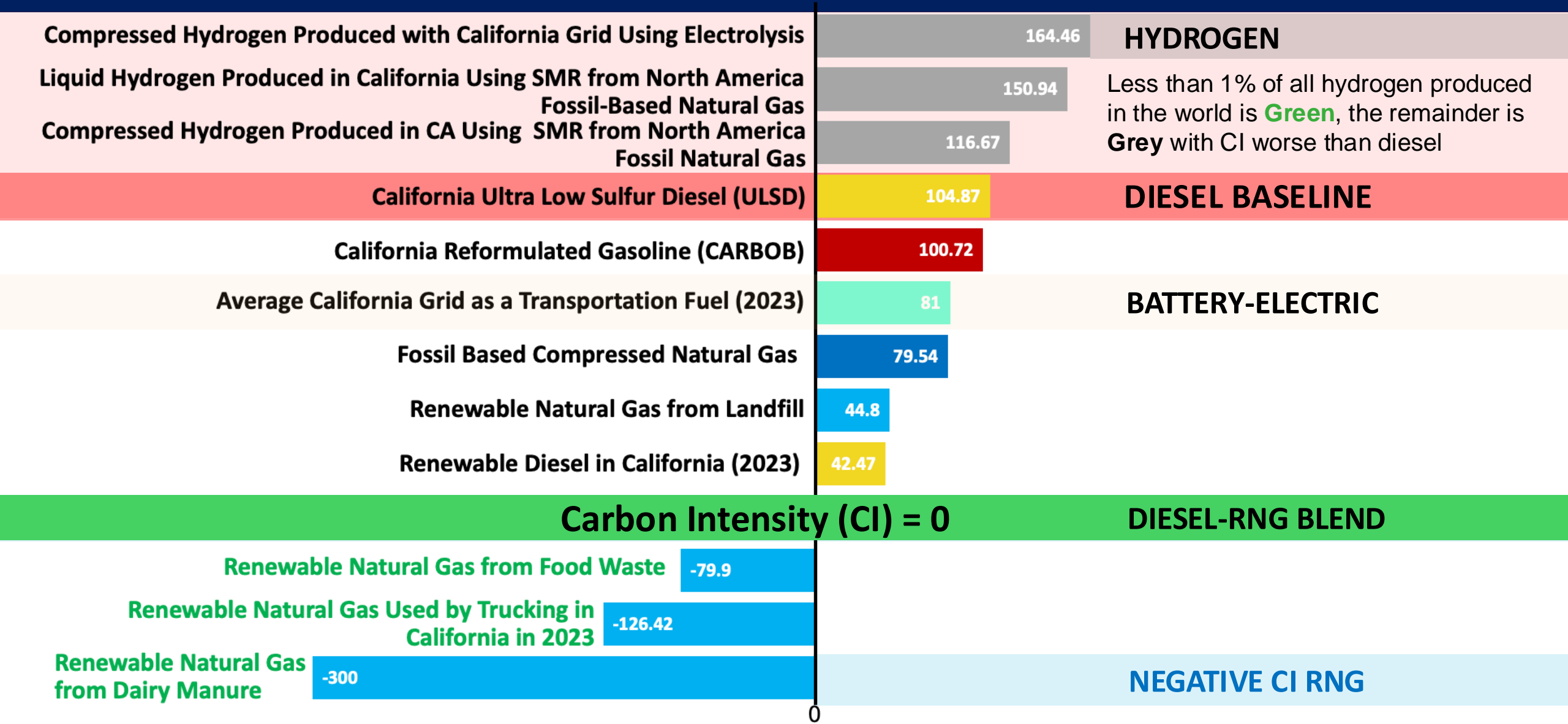
The terms **Tank-to-Wheel** and **Tailpipe Emissions** are subsets of well-to-wheel analysis, focusing specifically on a power source's criteria emissions during operation



**Remember: Technology Tackles NOx and PM, While Clean Fuels Eliminate GHG Emissions**



# Fuel Choices for Managing GHG Emissions in Rail: Lowest Technical and Cost Risk is to Blend Negative CI Renewable Natural Gas (RNG) with Diesel in Advanced Ultra Low-NOx Diesel Engines – Minimal Operation Changes Required by the Railroads



Source: CARB 2022 Carbon Intensity (CI) Lookup Table for Gasoline and Diesel and Fuels that Substitute for Gasoline and Diesel (gCO<sub>2</sub>eq/MJ)

# The Physics Behind Battery and Fuel Storage Significantly Impacts Cost, Operations and Public Safety in Line Haul Operations - Use of a Tender Should be the Last Option

**Increased Risk with Tenders:** The use of tenders for line haul operations introduces higher risks, adding congestion and hazardous materials to railways that reduce public safety

Tenders for battery, hydrogen, or RNG storage, are costly to build, test, refuel, and operate. Note that even catenary systems would require battery tenders to guarantee 24/7 operation

## Challenges in Transporting Hydrogen:

Transporting large amounts of hydrogen presents significant challenges. According to the U.S. Department of Energy, it would require 14 hydrogen tanker trucks to deliver the same energy as one diesel tanker truck

An **ideal solution** would combine the zero NOx, PM, and GHG emissions of RNG-powered locomotives with the cost, operational, and safety advantages of diesel-powered locomotives – **no tender required**



## DIESEL

Two Tier 4, 4500 hp diesel line haul locomotives, each holding 4,700 gallons of diesel, will go 1,500 miles.



## RNG

Two 5600 hp RNG-Electric line haul locomotives, each holding 2,500 DGEs of RNG, and ONE 11,800 DGE RNG tender, will go approximately 2,500 miles.



LA → CHICAGO  
without refueling!



## L-HYDROGEN

Two 4500 hp hydrogen fuel cell line haul locomotives, each holding 350 kg of hydrogen, and Two 5,000 Kg liquid hydrogen tenders, will go approximately 1,500 miles.



## G-HYDROGEN

Two 4500 hp hydrogen fuel cell line haul locomotives, each holding 350 kg of hydrogen, and Four 2,250 Kg gaseous hydrogen tenders, will go approximately 1,500 miles.



## BATTERIES

Two 4400 hp 100% battery line haul locomotives, each with 2,400 kW-hr of battery storage and Eight 8,000 kW-hr battery tenders, will go approximately 750 miles.





# Total-Zero™ Diesel-RNG Dual Fuel Line Haul Locomotive - No Tender Required!

- ✓ Can be retrofitted to any existing switcher or line haul platform
- ✓ Near Zero NOx
- ✓ Zero PM
- ✓ Zero GHG emissions

OptiFuel's Diesel-RNG Dual Fuel locomotives will enable railroads to **select any blend of RNG and diesel to achieve their SBTi targets for GHG emissions**



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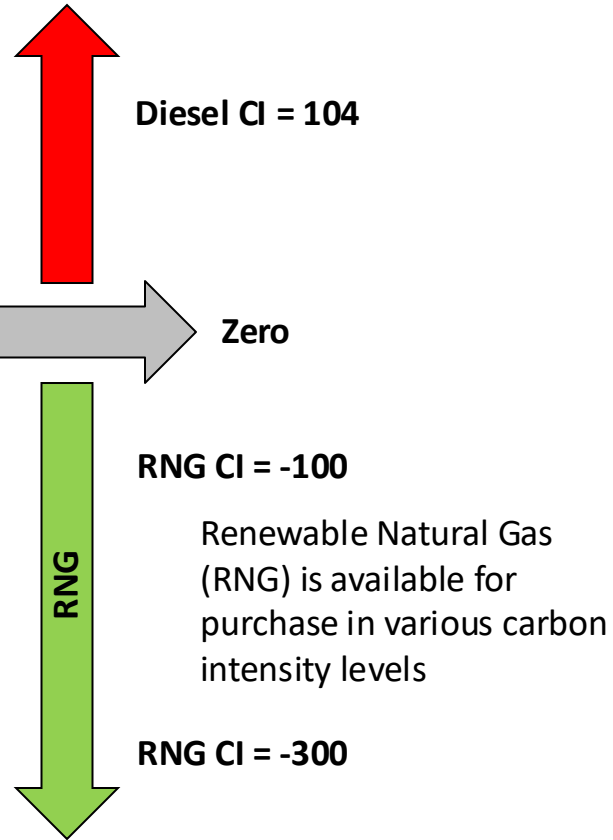


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# Neutralize GHG Emissions by Combining Fuels with a Positive Carbon Intensity (CI) with a Small Percentage of NEGATIVE CI Fuels

OptiFuel's approach enables you to **choose any blend of diesel and RNG** to achieve your SBTi targets on time and within budget

**Global Greenhouse Gases**  
eg CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O



CRITERIA EMISSIONS (g/bhp-hr)		CARBON INTENSITY (CI) DUAL FUEL BLEND CALCULATIONS (gCO <sub>2</sub> eq/MJ)						
NOx	PM	Total Gallons Fuel in DGE	Diesel Gallons (CI:100)	RNG Gallons	RNG CI	% RNG	Blended CI	CI Compared to Class 8 Trucks - Divide by 3
0.035	0.001	6600	4400	2200	-200	33%	0.00	0.00
0.035	0.001	6000	5000	1000	-300	17%	33.33	11.11
0.035	0.001	6600	4400	2200	-200	33%	0.00	0.00
0.035	0.001	6000	5000	1000	-300	17%	33.33	11.11
0.035	0.001	6600	4400	2200	-200	33%	0.00	0.00
0.035	0.001	6000	5000	1000	-300	17%	33.33	11.11
0.035	0.001	6600	4400	2200	-200	33%	0.00	0.00
0.035	0.001	6000	5000	1000	-300	17%	33.33	11.11
0.035	0.001	6600	4400	2200	-200	33%	0.00	0.00
0.035	0.001	6000	5000	1000	-300	17%	33.33	11.11



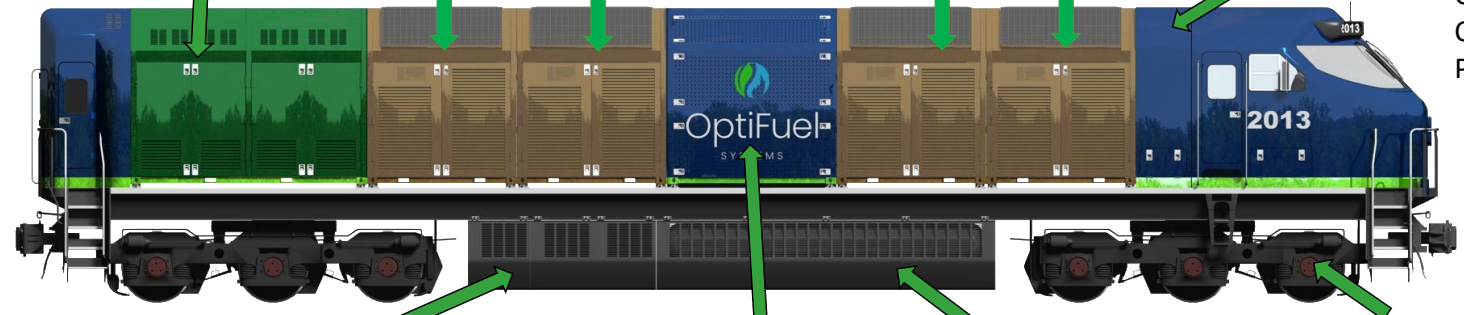
# OptiFuel's Total-Zero™ 5000 hp Diesel-RNG Dual Fuel Hybrid Line Haul Locomotive is Scheduled to Begin Testing in 2025 at FRA's TTC



- CAF AC Traction System Inverters
- Dynamic Braking Grid
- 500 hp LFP Batteries with Regenerative Braking



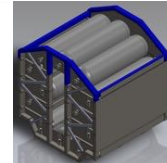
Baseline: Eight 690 hp Diesel-RNG Dual Fuel Quick-Power™ QD Modules (5,500 hp total)



Bathroom

Crashworthiness Cab and Platform

Below deck RNG/H2 Onboard Storage QD Modules with 500 DGE of RNG



RNG Onboard Storage QD Module with 1,000 DGE of RNG

4,500 Gallons of Diesel

Six CAF AC Traction Motor and Gearbox Combos

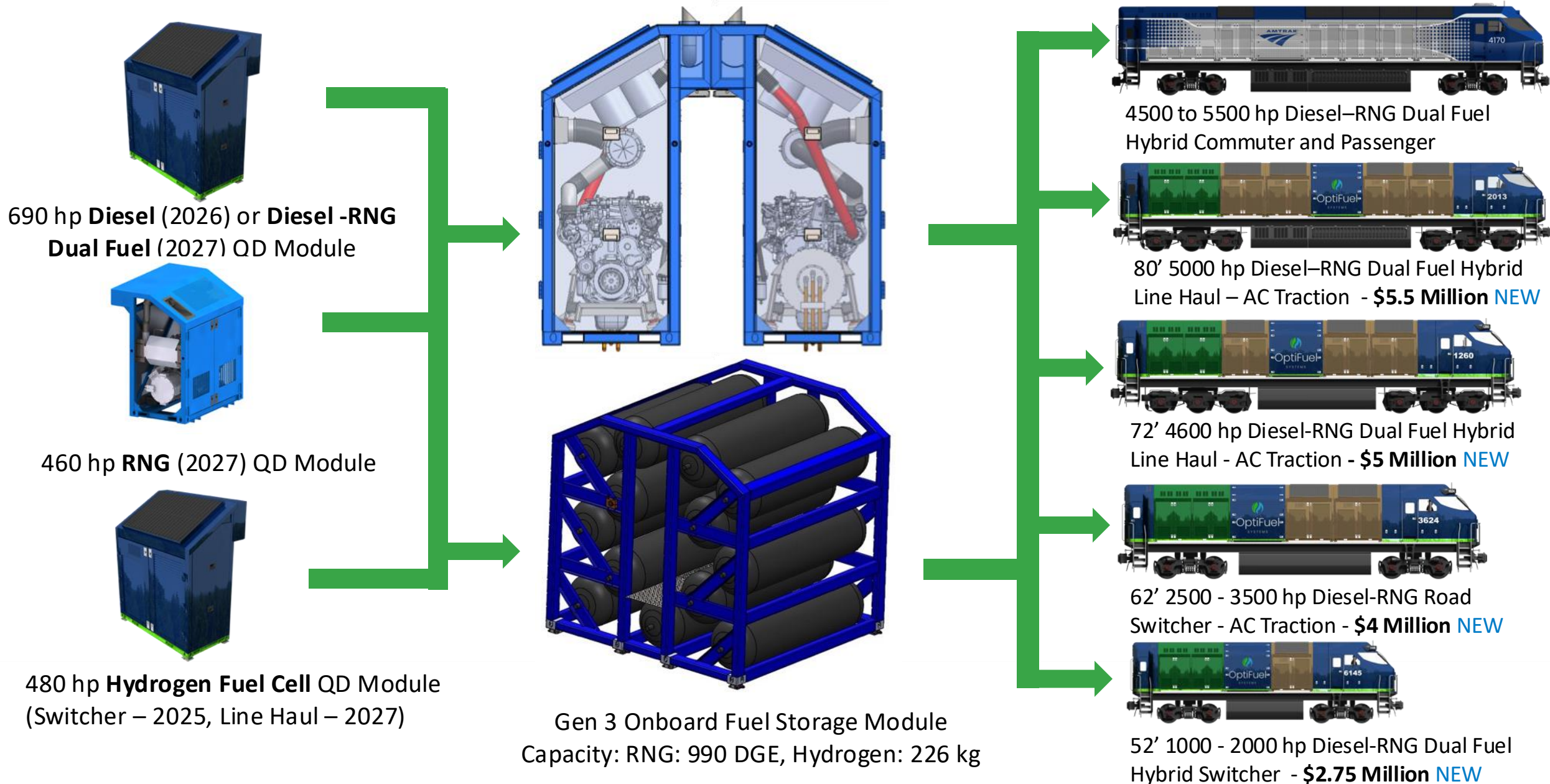
# OptiFuel Modular 5000 hp Diesel-RNG Dual Fuel Hybrid Line Haul Locomotives With ZERO GHG Emissions - Available in 2027 with Expected FRA Concurrence

- **CAN BE RETROFITTED TO ANY EXISTING LINE HAUL PLATFORM**
- Dual Fuel System That Can Run 100% Diesel and Dual Fuel Mode That Can Run 65% Diesel and 35% RNG
- **GHG Emissions with Carbon Intensity of ZERO Running 65% Standard Diesel with CI of 100 and 35% RNG with a CI of Negative 200**
- **Criteria Emissions – Available in 2027 with FRA Concurrence: NOx: <0.035 g/bhp-hr and PM: <0.002 g/bhp-hr**
- Up to 20% Less Diesel Use Than Tier 4 Diesel, Reducing GHGs by the same amount
- Redundant Power for Extreme High Availability and Reliability to Guarantee Tractive Power – 5500 hp IC Diesel and 500 hp Battery Total Power for a total Peak Power of 6000 hp
- CAF AC Traction with Regenerative Braking - Can Maintain Full Tractive Effort Even with Loss of One Traction Motor
- 6,500 Gallon Range Capable of Traveling 2,500 miles - **NO TENDER REQUIRED**
- On-track maintenance and 1-hour module replacement minimizes disruptions and out-of-order assets
- Less than 2 hours of engine module maintenance every 180 days
- Lower lifetime operating expenses
- 30-year locomotive lifespan, with the flexibility to transition to alternative fuels like green hydrogen if available





# 2 to 8 Diesel, RNG or Hydrogen Power and Fuel Storage QD Modules Are Used To Assemble 1000 hp to 5,000 hp OptiFuel Total-Zero™ Hybrid Locomotives



# FRA Concurrence Expected by 2027 for 3 Standardized Switcher and Line Haul Locomotive Power Modules – Diesel, RNG, & Hydrogen

## Diesel and Diesel-RNG Dual Fuel Power Module

- **Power:** Up to 670 hp IC engine with 750 hp motor/generator
- **Fuel:** Biodiesel blends up to 20% and renewable diesel blends up to 100% (up to 33% RNG in dual fuel)
- **Emissions:**
  - **Compliance with 2027 EPA and CARB regulations**
  - **NOx: <0.035 g/bhp-hr, PM: <0.002 g/bhp-hr**
  - **88% cleaner than proposed CARB Tier 5 Locomotive Standard**
  - **In Dual Fuel Mode – GHG emissions can achieve ZERO Carbon Intensity (CI)**
- **Concurrence Target:** 2026 (diesel), 2027 (dual fuel)

## RNG Power Module

- **Power:** Up to 500 hp IC engine with 750 hp motor/generator
- **Fuel:** Renewable Natural Gas (RNG)
- **Emissions:**
  - **NOx: 0.000 g/bhp-hr, PM: 0.000 g/bhp-hr**
  - **GHG emissions can achieve ZERO Carbon Intensity (CI)**
- **Concurrence Target:** 2027

## Ballard FCMove™-XD Hydrogen Fuel Cell Module

- **Power:** 360 kW (480 hp)
- **Fuel:** Hydrogen
- **Emissions:**
  - **NOx: 0.00 g/bhp-hr, PM: 0.000 g/bhp-hr**
- **Active Program:** Sierra Northern Railway (SNR) Hydrogen Switcher Locomotive Program (4 units)
- **Concurrence Target:** 2025



5500 hp Diesel Configuration



35 feet (8 Modules)

5500 hp Diesel-RNG Dual Fuel Configuration



45 feet (9 Modules)

## 102" Wide Quick-Power™ Quick-Disconnect (QD) Power Modules

- Standardized Module is used across all switcher & line haul locomotives
- Modules Typically in Pairs – Available 123" Across with 20" Wide Center Walkway for Line Haul and 79" Across for Switchers

## Eight 102" OptiFuel Quick-Power™ Quick-Disconnect (QD) Diesel-RNG Power Modules

## Eight 102" OptiFuel Quick-Power™ Quick-Disconnect (QD) Diesel-RNG Dual Fuel Power Modules with One RNG Fuel Storage Module

- 1,000 DGE storage capacity



# All Switcher and Line Haul Locomotive Fuel Storage Systems Are Expected to Have FRA Concurrence by 2027 – Storage Systems Are Certified to Hold RNG or Hydrogen

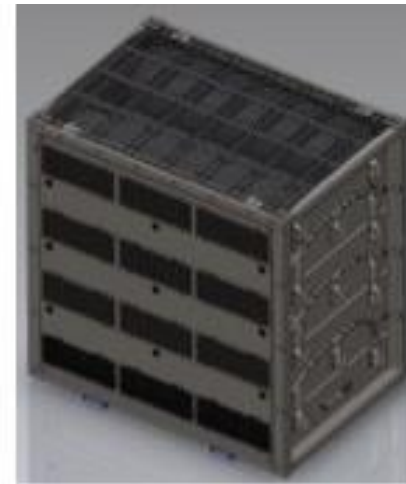
- Onboard RNG Storage for Switchers (IHB)
- **Received FRA Concurrence in 2020**



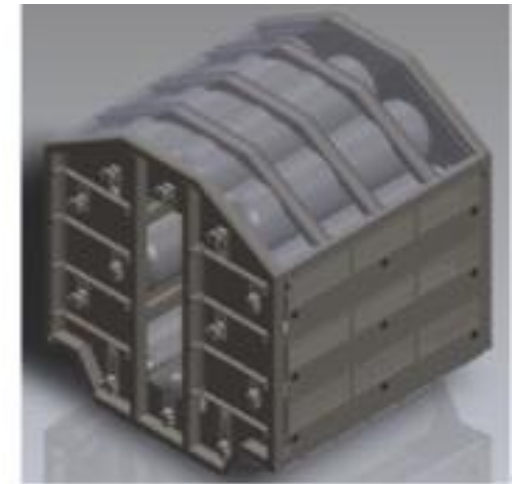
- Onboard RNG/Hydrogen Storage for Switchers (SNR)
- **FRA Concurrence for Testing End of 2024**
- **Expected FRA Concurrence for Operations in 2025**



- Version 2 Onboard RNG/Hydrogen Storage for Switchers (SNR) - High Speed
- Testing at TTC
- **Expected FRA Concurrence for Operations Early 2026**

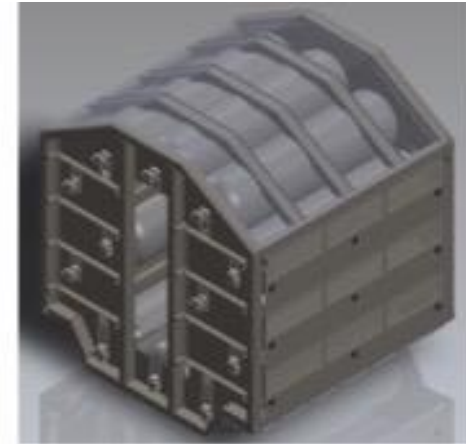


- Onboard RNG/Hydrogen Storage for Line Haul (DOE) - High Speed
- Testing at TTC
- **Expected FRA Concurrence for Operations Early 2027**



# Accelerated Impact and Vibration Testing of Onboard High Pressure RNG/Hydrogen Onboard Storage Modules for Locomotives

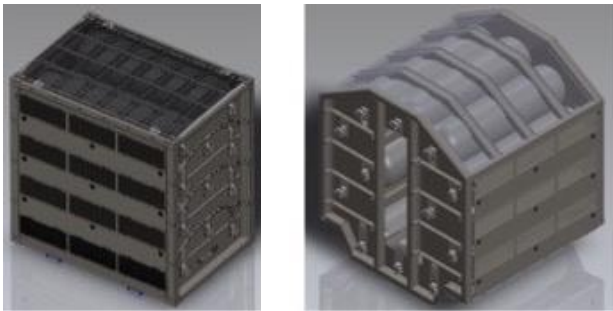
- OptiFuel is working with ENSCO engineering at TTC facilities to develop a test program to validate the reliability of our **High Pressure RNG/Hydrogen Onboard Storage Module design** for switchers and line haul alternative fueled locomotives to support our 5000 hp Diesel-RNG Dual Fuel Hybrid Line Haul Locomotive testing in 2026 at FRA's TTC
- Currently, there is no data on the long-term vibration and fatigue effects on the reliability of high pressure RNG/hydrogen onboard storage systems for switcher and line haul locomotives
- This evaluation and test program will **use an existing fully instrumented RNG/ hydrogen onboard storage module** developed on OptiFuel's DOE's zero emission line haul locomotive program
- Using the the Simuloader Unit (SMU) located at the **Rail Dynamics Laboratory (RDL) at the TTC**, the onboard storage system will undergo accelerated impact and vibration testing to simulate 1 million miles of revenue service. This testing will assess its long-term safety and reliability and compare results to analytical projections





# Crash Testing of Onboard High Pressure RNG/Hydrogen Storage Module for Alternative Fueled Locomotives

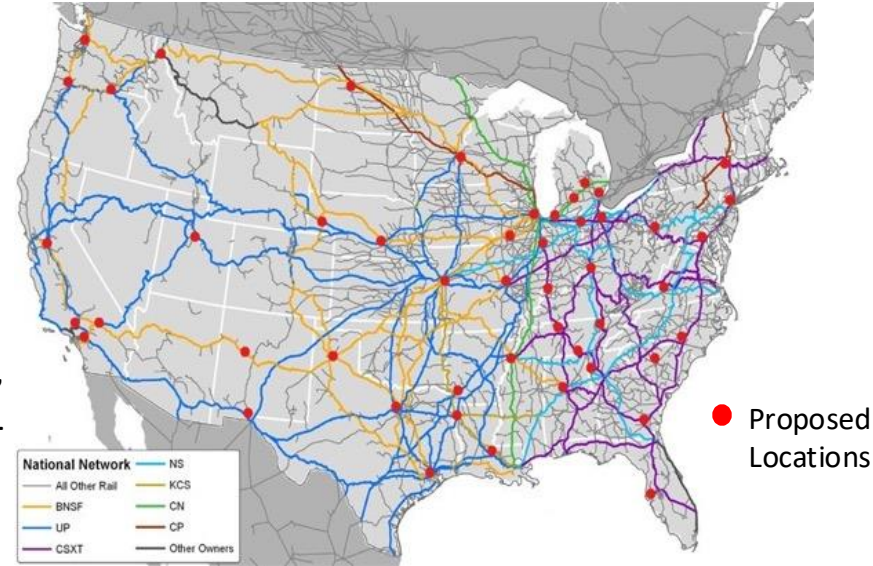
- OptiFuel is also working with ENSCO engineering at TTC facilities to develop a test program to validate the survivability of our **Onboard High Pressure RNG/Hydrogen Onboard Storage Module** design for switchers and line haul alternative fueled locomotives to support our 5000 hp Diesel-RNG Dual Fuel Hybrid Line Haul Locomotive testing in 2026 at FRA's TTC
- This program has two objectives:
  - 1) Demonstrate the **survivability** of an RNG/hydrogen onboard storage module on a line haul locomotive when hit by a Class 7 trucks at a rail crossing
  - 2) Demonstrate a **rapid gas-release system** on the module for major accidents with fire
- **Collision impact testing** at the TTC will demonstrate the **crashworthiness** of an onboard storage module mounted on an existing locomotive frame during a Class 7 truck impact



**RAILROAD IMPACT** - Provides rail environment-specific test data for advanced gaseous fuel safety systems designed to address the unique characteristics of freight and passenger railroad operations

# Minimal Infrastructure Expansion Required: Integrating RNG Dispensers to Existing Diesel Islands at up to 60 Class 1 Railroad Refueling Sites

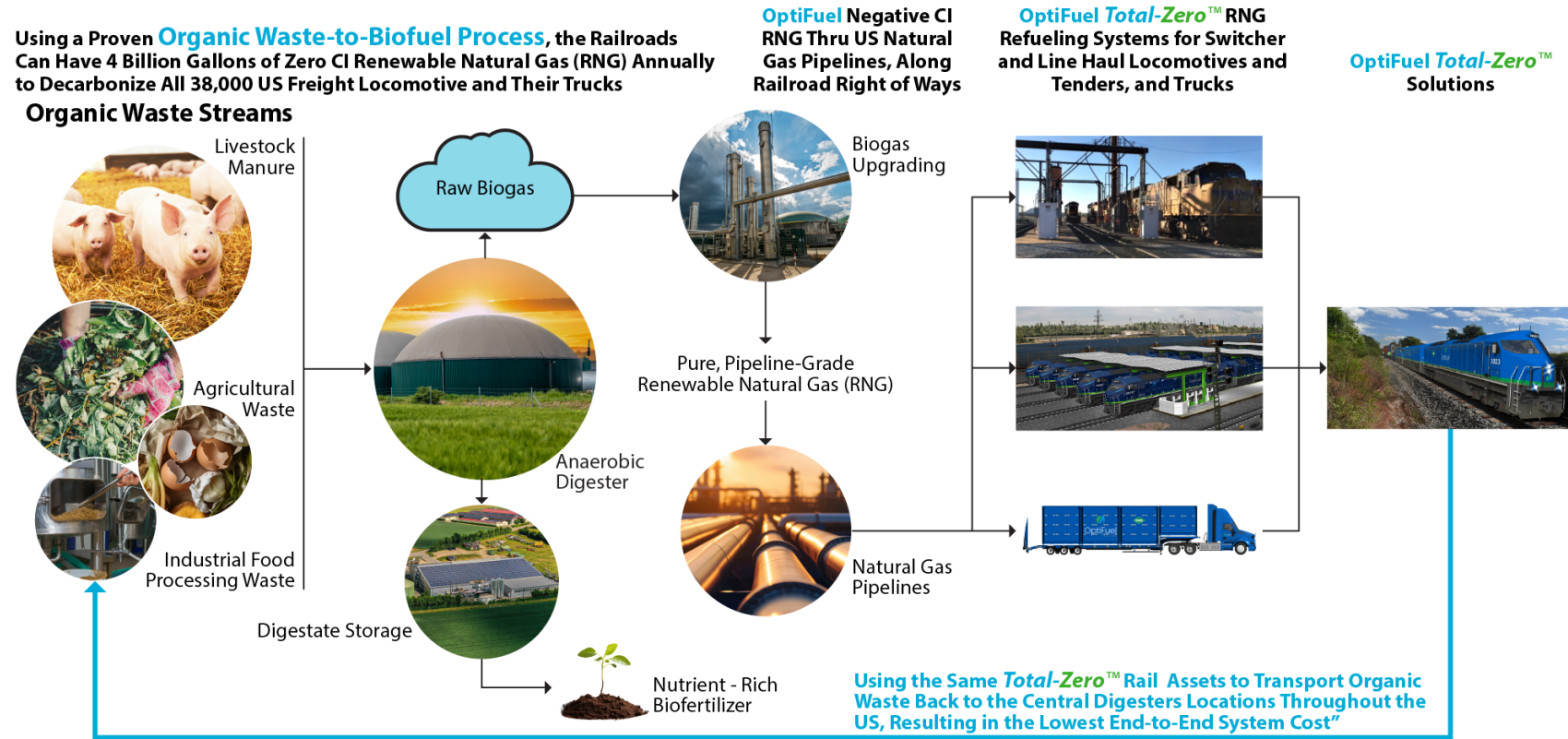
- RNG will be delivered to railroad refueling sites through existing natural gas pipelines, a highly efficient 3-million-mile network
- Each RNG dispenser can refuel 2,500 diesel gallon equivalents (DGE) of RNG into a line haul locomotive every 30 minutes, facilitating the refueling of 48 line haul locomotives (120,000 DGE) over a 24-hours period
- The refueling systems are scaled-up versions of OptiFuel's 2013 refueling station at the Indiana Harbor Belt Railroad. Additionally, OptiFuel offers scaled-down versions for bulk transfer and trailer-based mobile refueling
- Watch an IHB Railroad employee refuel their dual fuel locomotives in this video: <https://youtu.be/QSkvFhauUAW>





# To Guarantee Availability of RNG for the Next 30 Years, OptiFuel, in Partnership with the Railroads, Will Build 200 RNG Production Sites to Produce 1 Billion DGEs of RNG Annually

- Over 10 years, OptiFuel will build 200, Negative 200 CI RNG production sites around the US, each capable of producing 5 million DGEs of RNG annually
- The total infrastructure investment required to construct these 200 RNG production sites and install RNG refueling systems at 60 railroad fuel stations is approximately \$11.2 billion
- OptiFuel aims to offset this expense through Federal and State Alternative Fuel Tax Credits generated from the sale of RNG at the stations over the 10-year period.
- OptiFuel’s approach will provide the railroads with a fixed-rate fuel price for the first 10 years, with the option to extend for another 10 years. The projected fixed-rate price of RNG is estimated to be between \$1.50 and \$2.50 per DGE



**A Sustainable, Circular Economy With Affordable, Hard-to Abate, *Total-Zero™* Transportation and Mobile Power Assets Using Low-Cost RNG**





# OptiFuel

SYSTEMS

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