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solutions that transform

Project ID # TI142

Field Demonstration of a Near-Zero, Tier 5 Compliant, Natural Gas Hybrid Line-Haul Locomotive

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Presenters – Ted Barnes, P.E.; Bart Sowa

GTI Energy, June 14, 2023

Overview

Timeline

- Project start Oct. 1, 2020
- Project end Dec. 31, 2024
- 34% complete

Barriers and Targets

- Viable near-zero emission technology available for Class I linehaul locomotives
- Higher system efficiency with 20-40% fuel consumption reduction
- Exceed proposed Tier 5 emissions

Budget

- Total project $5,199,733
  - DOE share $2,599,733
  - Contractor share $2,600,000
- Funding for FY 2022 $1,280,679
- Funding for FY 2023 $2,797,079 (expected)

Key Partners

- GTI Energy - lead
- OptiFuel, FMW Solutions, Cummins
- Collaboration with Transportation Technology Center (TTC)

Project Objectives

Objectives

Demonstrate Tier 5-capable locomotive built with commercially available and reliable components

Demonstrate the use of near-zero on-road engine for use in off-road markets, opening new markets such as rail and marine

Quantify benefits of multi-engine hybrid locomotives (reduce fuel consumption by 20% to 40%)

Showcase benefits of CNG and RNG use in rail application: reduce fuel cost, reduce criteria pollutants, lower GHG emissions

Collect data to validate durability and reliability

Impacts

Acceptance of the technology potential by Class I railroads

Reduced operating costs, emissions and noise of linehaul rail operations

Improved fuel and infrastructure diversity

Enable old rolling stock conversions

VTO TI Goals

Improved fuel diversity – use of RNG and CNG in rail linehaul operations

Improved local resiliency – RNG and CNG infrastructure is very reliable, molecules are locally produced

Reduced GHG emissions - proposed technology will improve fuel efficiency while reducing criteria pollutants (NO_x, PM) and CO_2

Project Approach

Budget Period 1

Engineering / Procurement Plan

- Near-Zero Locomotive Engineering
- Locomotive Procurement
- Production Plan
- System, TTC, and Operational Test Plan

Budget Period 2

Procurement / Production

- Procure Locomotive
- Locomotive Production
- Update Engineering Drawings
- Update System, Operational Testing Plan

Budget Period 2

Testing / Validation

- System and Sub-system Locomotive Testing
- Validation Testing and Reporting
- Locomotive Operational Testing and Validation
- Final Testing Reports and Final Report

The production plan relies on use of mature components and technologies and experienced industry experts, with volume production expected within 20% of the conventional locomotive.

Milestones

Phase 1 Milestones	
Locomotive Specifications Compete	✓
Engineering Design Status at ≥33%	✓
Engineering Design Status at ≥66%	✓
Engineering Design Status at 100% and Production Plan Complete	✓
Design Validated to Achieve System Specifications	✓
Go/No-Go	

10/1/2020-12/31/2022

Phase 2 Milestones
Procurement Complete and Production Started
Production Status at ≥33%
Production Status at ≥66%
Locomotive Production Status at 100% and Test Plan Complete
Production Complete and Ready for testing and Validation
Go/No-Go

1/1/2023-12/31/2023

Phase 3 Milestones
Acceptance and Validation Complete
Association of American Railroads (AAR) Testing Started
AAR Testing Complete
Operational Testing & Validation Started
Program Complete

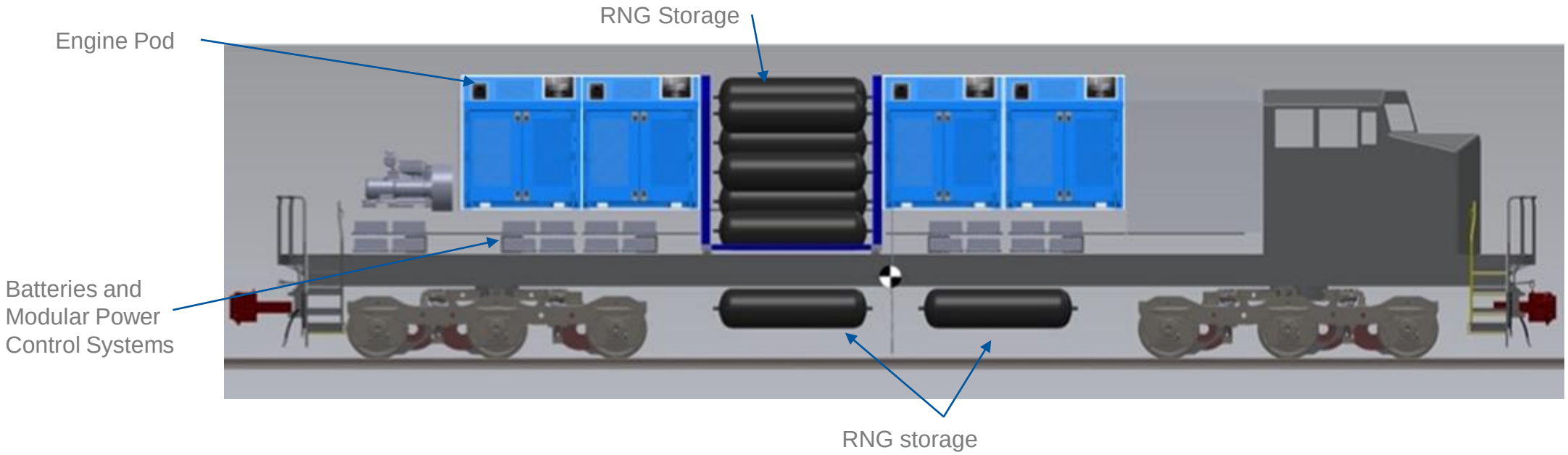
1/1/2024-12/31/2024

- COVID-19 impacted staffing levels and required no-cost extension of Phase 1
- Pending Budget Period 2 continuation approval
- Design work and performance analysis done to date satisfy the Go/No-Go criteria:
  - 4,000 hp output and 1,800DGE onboard storage

Project Accomplishments and Progress

Locomotive Specifications

– An existing EMD SD70M-2 locomotive, 74 foot long with two 3-axle trucks in a C-C configuration. Preliminary designs for power generator modules, batteries and charging system and fuel storage and delivery can be fit available space. Go/No-Go criteria: 4,000 hp output and 1,800DGE onboard storage



Project Accomplishments and Progress (Continued)

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Duty-cycle modeling confirmed that performance targets can be achieved

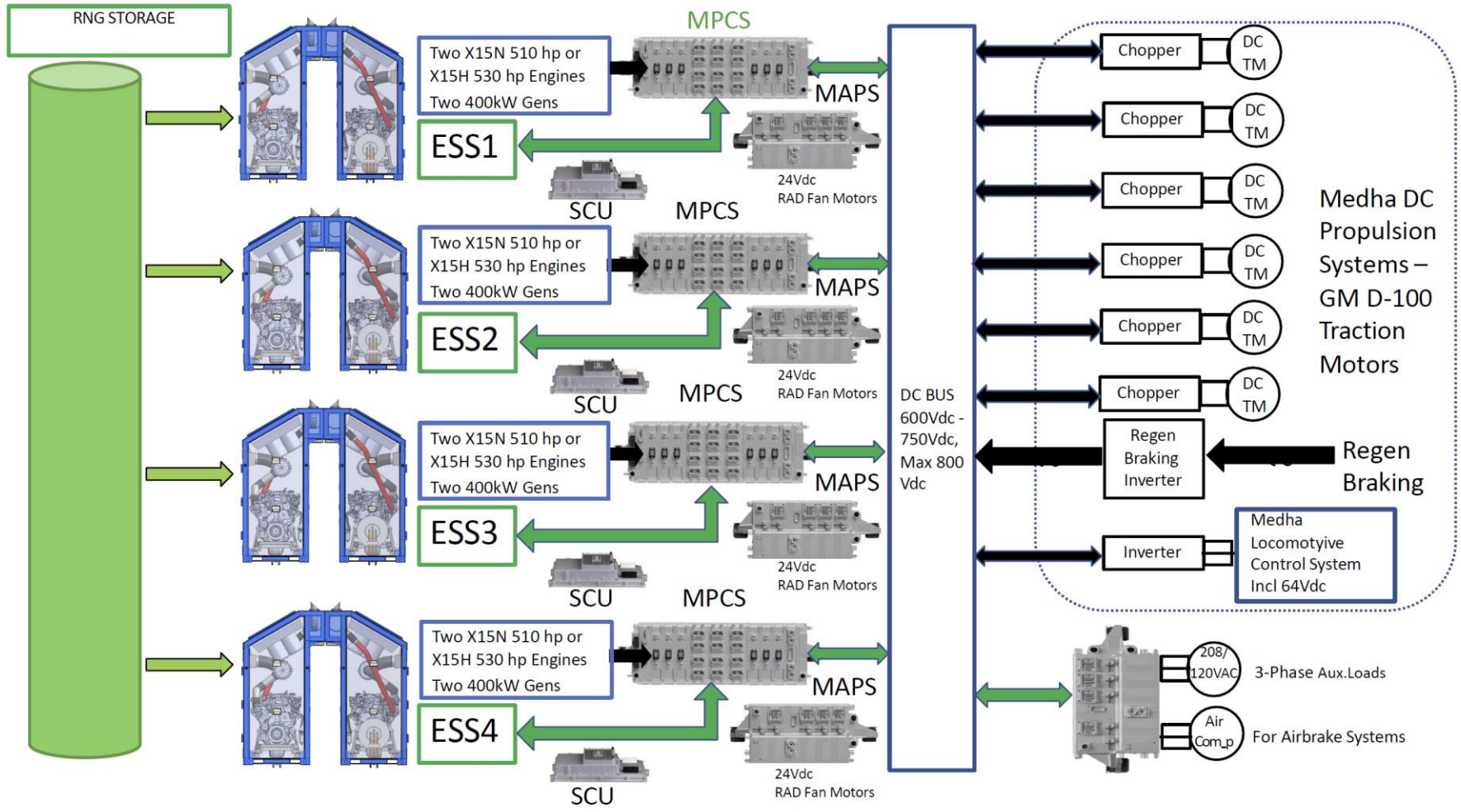
EPA Line Haul Duty Cycle (Time)	Total Annual Hours With No ESS System	Total Annual Hours With ESS System	Percentage Total Annual Hours With With ESS System	EPA -Percentage Power Notches Schedule	8 ISX12N Total Horsepower Notch Schedule	Virtual Engine #1 HP ISX12N	Virtual Engine #2 HP ISX12N	Virtual Engine #3 HP ISX12N	Virtual Engine #4 HP ISX12N	Virtual Engine #5HP ISX12N	Virtual Engine #6HP ISX12N	Virtual Engine #7HP ISX12N	Virtual Engine #8HP ISX12N	BatteriesPower (Hp)	Batteries Power (kW-hr)		Check Total Horsepower
		0.3			4000												
50.50%	3,030	2,121	41.66%	1%	40	40	0	0	0	0	0	0	0		0		40
	-	-	0.00%	0%	0	0	0	0	0	0	0	0	0		0		0
6.50%	390	390	7.66%	5%	180	180	0	0	0	0	0	0	0		0		180
6.50%	390	390	7.66%	12%	460	230	230		0	0	0	0	0		0		460
5.20%	312	312	6.13%	24%	940	315	315	315	0	0	0	0	0		0		945
4.40%	264	264	5.19%	35%	1400	350	350	350	350	0		0	0		0		1400
3.80%	228	228	4.48%	49%	1940	330	330	330	330	330	300		0		0		1950
3.90%	234	234	4.60%	64%	2560	330	330	330	330	330	310	300	300		0		2560
3.00%	180	180	3.54%	85%	3400	375	375	375	375	375	375	375	375	400	298.4		3400
16.20%	972	972	19.09%	100%	4000	375	375	375	375	375	375	375	375	1000	746	1066	4000
								AVG ISX12N	44%							8	
100.00%	6,000	5,091	100.00%			100.00%	50.68%	43.02%	36.89%	31.70%	31.70%	27.22%	27.22%	22.63%			Percent Total Hours
		Running Hours	Running Hours %			5,091	2,580	2,190	1,878	1,614	1,614	1,386	1,386	1,152	746	Required Batteries = Battery Power/0.7	Total Hours
							% Time of Load per	44%	2,217	Hours a year			Total Hp-Hrs	1,044,000		1,066	

Used EPA line haul duty cycle and the EPA percentage power notch schedule to calculate the required horsepower at each notch level from the 3,200 hp from the eight 400 hp RNG engine pods and 750 kw (1,000 hp) from the four battery packs. It is based on 5,091 locomotive operating hours a year.

Project Accomplishments and Progress (Continued)

System Architecture

- 5th iteration design
- Fuel Storage
- Engine (Genset) Pods
- Control System
- DC Bus
- Propulsion System



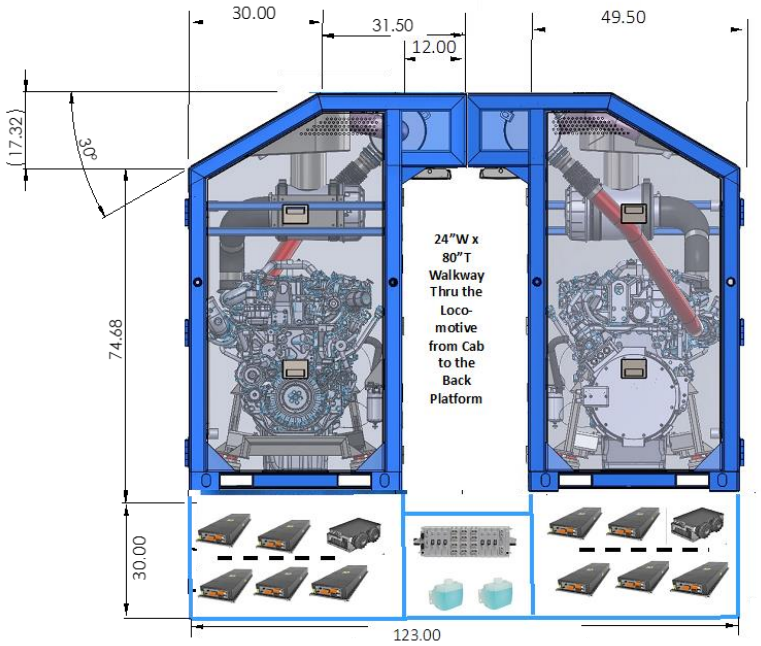
Project Accomplishments and Progress (Continued)

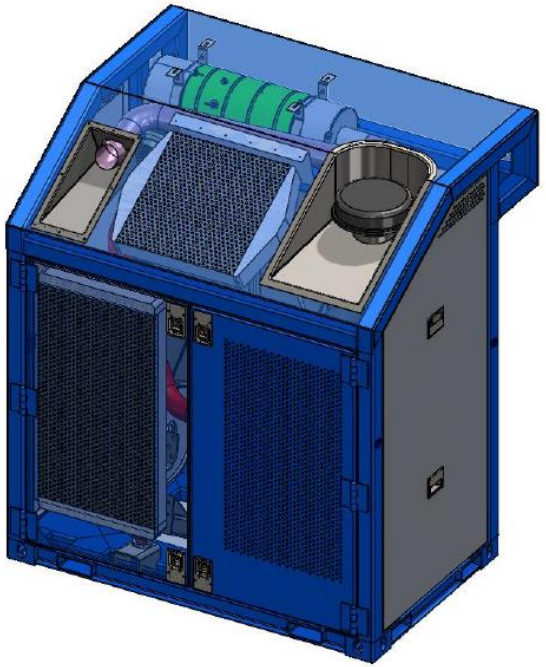
Engine Module (Pod) Design

– Designed to enable quick installation / removal with ISO corner locks to ensure stability for everyday operation as well as crash survivability

– Component layout ensures overall accessibility and serviceability

– Pods can accommodate Cummins 12-liter and 15-liter engines

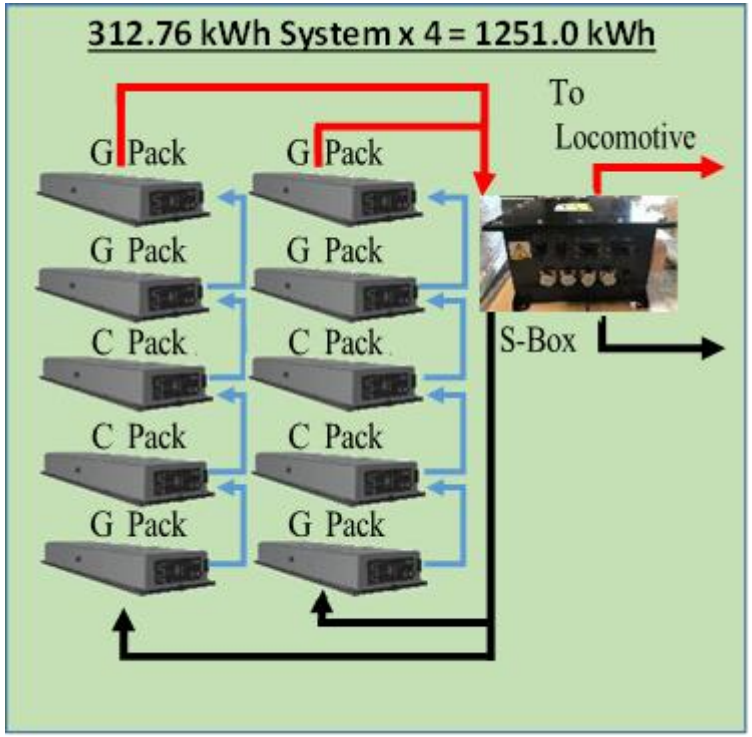




Project Accomplishments and Progress (Continued)

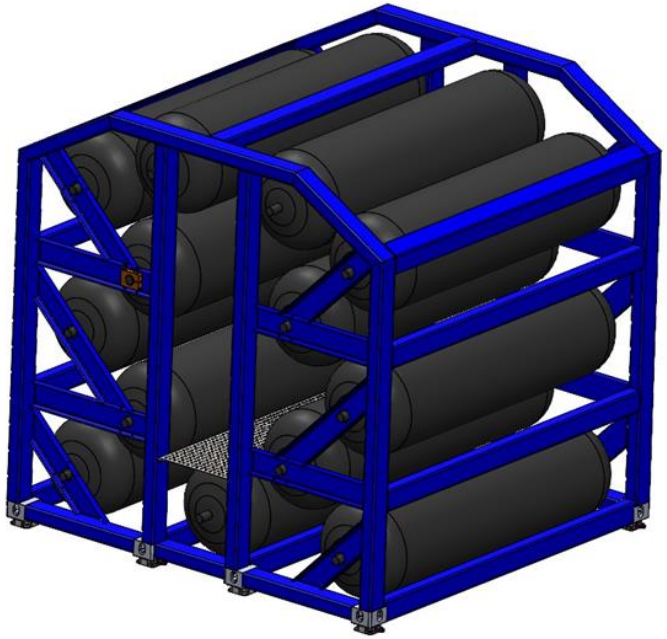
Battery Module

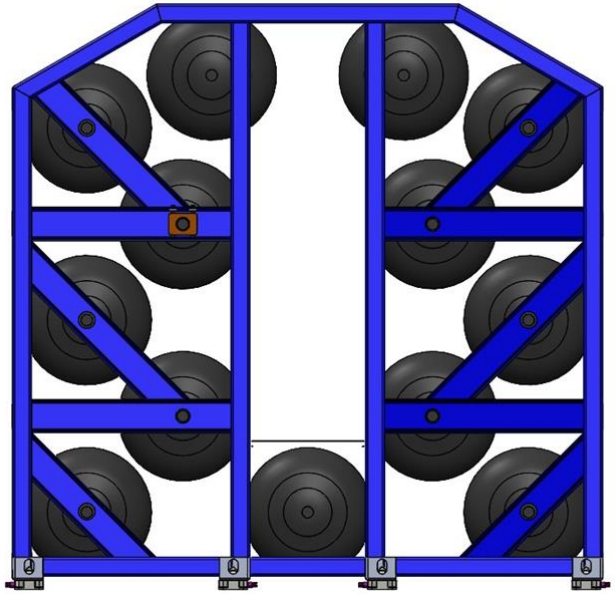
- 313 kWhr
- LFP Batteries
- MPCS and Two Chillers
- Off-the-shelf packs
- Nominal voltage 686VDC



Project Accomplishments and Progress (Continued)

CNG/RNG On-deck Storage Module





1,300 DGE storage module has a 20” x 80” walkway in the middle of the unit to allow operators to go from the front to the back of the locomotive. Additional storage tanks are located under locomotive deck.

Project Accomplishments and Progress (Continued)

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Task 1.2 – Locomotive Procurement:

The team is in the process of locating and procuring a used SD70M-2 locomotive.

Task 1.3 – Production Plan:

The plan is to utilize Railserve, a division of Marmon Holdings, to assemble the locomotive in Longview, TX. Expect to secure the locomotive in June 2023 to begin preparation to start assembly in October 2023.

Task 1.4 – System, TTC, and Operational Test Plan:

Testing will occur at FRA's Transportation Technology Center (TTC), starting in Q2 2024. Operational demonstration will be conducted either at TTC on the test track, or with Patriot Rail in California or Utah.

Collaboration and Coordination Among Project Team

Project Collaborators

- DOE's Vehicle Technologies Office – funding agency
- GTI Energy - prime recipient
- OptiFuel - subcontractor, lead technology developer
- FMW Solutions, Cummins, Medha Transportation, BAE Systems – key technology providers
- Optifuel, Dominion, Utilization Technology Development (UTD) - industry stakeholders, cost share
- Railserve – manufacturing and assembly services
- FRA's Transportation Technology Center (TTC) – testing services

- GTI Energy is an experienced VTO collaborator
- The team has decades of experience in R&D, technology development and rail industry
- GTI Energy has successfully collaborated in the past with OptiFuel, FMW, Cummins and BAE

Contribution to Energy Equity and Environmental Justice

- Due to the scale of this project, it is not expected to make an immediate and direct contribution to the Energy Equity and Environmental Justice
- The project, however, will enable broader adoption of the technology
- At scale, the technology will contribute to energy equity and environmental justice by reducing criteria pollutants from locomotive used in railyards
- Railyards tend to be in areas where underserved populations have some of the poorest air quality
- Similarly, when used in passenger transit applications, it will improve the air quality and reduce noise affecting the riders, operators, neighborhoods and urban areas

Summary Slide

Objectives:

Demonstrate commercially available components can be used to manufacture near-zero emissions line-haul locomotives with fuel economy improvements of 20 to 40%

Collect data to validate safety, durability, and operating competency to quantify advantages for the railroad industry and dispelling any concerns for new technologies

Approach:

Employ low-risk, conventional design – build – validate process utilizing off-the-shelf components

Key Accomplishments:

Completed conceptual design, production plan, selected major technology vendors

Next Steps:

Kick-off procurement, finalize detailed design, start manufacturing (2024)

Test and demonstrate the locomotive (2024)