Railroad Solutions

TwinPulse™

Locomotive Energy System

A Transformative Approach to Idle Reduction and Engine Cranking

What's on the Mind's of Class I Railroads in 2026?*

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1. **Operational Efficiency (through technology)**
2. **Sustainability and Emissions Reduction**
3. Infrastructure Investment and Network Resiliency
4. Growth & Operational Strategies
5. **Workforce Safety & Well Being**

TwinPulse™ addresses 3 of the top 5 issues currently facing Class I Railroads

A 55 kWh Lithium iron phosphate (LFP) energy module can concurrently reduce Locomotive idle time and serve as an improved cranking source for the Locomotive engine

Benefits Include:

- **Lower GHG Emissions**
- **Reduced Fuel Usage**
- **Keep key systems, like HVAC, operational while engine is off**
- **Significantly more reliable restarts = fewer stranding events**
- **Eliminate acid splash, hydrogen gas emissions, and arc flash incidents associated with Lead Acid batteries**
- **LFP batteries are less prone to Thermal runaway than Lithium-Ion**
- **Remote Connectivity that can provide operational insight**

* Source – Goggle Gemini aggregation of public data including ARA, GoRail, *Progressive Railroading* and company annual reports

TwinPulse™ will alter the way you think about Idle Reduction and Locomotive Restarts

Automated Engine Start/Stop System (AESS) system functionality which leverages 55 kWh of battery power to drastically improve idle reduction efficacy

Use the same energy module to crank the engine (in place of Lead Acids) and greatly increase locomotive Availability by practically eliminating failed to start incidents

Remote Dashboard allows you to monitor system performance and gain insights on how to increase savings and improve operational efficiency
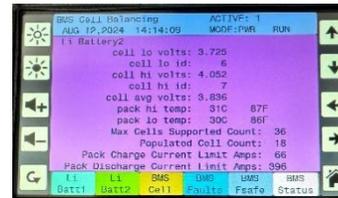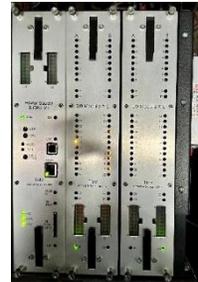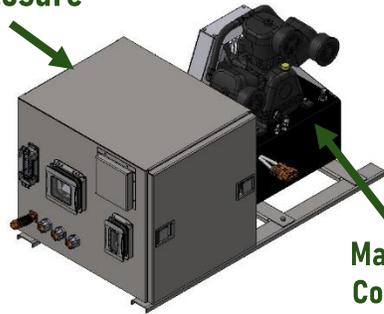
(2) 27.6 kWh Lithium Iron Phosphate Battery

Connectorized Industrial Enclosure

AESS Logic Control

Make-up Air Compressor

In Cab User Interface

Remote Dashboard w/Analytics

TwinPulse™ Represents the Next Generation in AESS Systems

Why Do Traditional AESS Systems Often Not Deliver the Desired Result?

The current generation of Automatic Engine Start/Stop Systems are highly binary (i.e. turn the locomotive almost completely off) and do not address the causes of locomotive engine restarts.

Reasons a Locomotive Exits/Can't Enter AESS mode*

1. Manual override to reengage a critical system (ex: HVAC)

2. Drop In Air Pressure Likely Due to Leaks

3. Discharge of Lead Acid Batteries

4. Maximum # of Daily Restarts Exceeded

* Source: Locomotive Mechanical Officers Association (LMOA) White Paper "AESS Issues and Challenges"

TwinPulse Leverages a 55 kWh LFP based Energy Module to Overcome these issues

TwinPulse performs all the functions of an AESS, while integrating 55 kWh of battery power, and a make-up air compressor, to greatly enhance Idle Reduction efficacy

1. TwinPulse Energy Module keeps Lighting, Safety, Analytic and most importantly HVAC Systems operational, mitigating the motivation for a manual override

2. System monitors air pressure (like an AESS) and activates the battery powered make-up compressor when air levels drop (unlike an AESS)

3. The TwinPulse LFP Energy module also serves as the locomotive cranking source, removing headaches of Lead Acids

4. The above listed capabilities and extended Energy Module run time significantly reduces the need to restart the engine

The TwinPulse Energy Module Can Power Key Locomotive Systems in Excess of 8 Hours

Reduced Idle Times Potentially Provide Benefits That Go Beyond Fuel Savings

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Reduced Maintenance Costs Through Fewer Restarts

Electric Starter replacement may decrease from yearly to every two years

Oil/Oil Filter and Fuel Filter replacement cycles my decrease from every 3 months to every 6 months

Mechanical Labor may decrease by ~ 200 hours a year

Improved Community Relations

Railyards are frequently located in densely populated urban areas – minimized idle time will reduce noise and odiferous emissions for those who live near by

Enhanced Crew Comfort & Safety

- Crews can continually operate in a temperature-controlled environment
- Walkways, steps and cab fully lighted to enhance safety
- Camera, Analytic and other useful systems stay active

Stop Worrying About Maintaining Lead Acid Batteries and if your Locomotives will Restart when you need them

Lead Acid Locomotive Batteries

TwinPulse LFP Locomotive Battery

1 Short Life Span – 2 to 3 years

2 Unreliable/prone to deep discharge events

3 Require constant maintenance

4 Acid Splash and arc flashes pose an associate safety risk

1 ~ 8 – 10 year expected life due to inherently better chemistry

2 Parallel wiring provides redundancy and a single battery with a 10% SOC can start the engine

2 StrandSafe™ technology enables a user–initiated override window to deliver maximum remaining energy for a restart

3 No manual maintenance or "topping off"

4 No Acid/Sealed system = greatly reduced safety risk

Stop Worrying About Maintaining Lead Acid Batteries and if Your Locomotives Will Restart When You Need Them

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Lead Acid Locomotive Batteries

TwinPulse LFP Locomotive Battery

Unlike Other Alternative Battery Solutions, TwinPulse™ is a Drop-in Replacement and Does Not Require Costly OEM Software Revisions

1. Short Life Span – ... expected life

2. Unreliable/prone to d...

3. Require constant mainte...

4. Acid Splash and arc flashes pose an associate safety risk

1. ... Parallel wiring provides redundancy and a single battery with a 10% SOC can start the engine

2. StrandSafe™ technology enables a user-initiated override window to deliver maximum remaining energy for a start

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Class 1 RRs are Spending Large Amounts on Sustainability & Fuel Reduction, But Do They Know if Their Investments are Providing a Payback?

The TwinPulse™ system offers Remote Connectivity and a Web Based Dashboard that can validate improved idle reduction efficacy and offer insight on how to generate even further savings

The Dashboard includes a highly visible widget which quantifies fuel savings and GHG emissions avoided

Fuel Savings & Environmental Impact

Energy Module Time	Fuel Saved	Cost Savings	CO_2 Avoided
67d 17h 17m 51s	9589.3 gal	$29726.69	220,553 lbs

Energy Module Exit Overrides

Short TH/DIR exits without subsequent work activity - likely operator overrides.

Override Sessions	Lost Energy Module Time
94	2d 8h 1m 4s

Near-Miss Overrides

TH/DIR resets without subsequent work activity - likely operator overrides preventing energy module entry.

Override Events	Lost Energy Module Time
30	19h 39m 17s

Opportunities for further savings are highlighted by displaying instances where the locomotive either exited Battery Mode or was unable to enter it due to manual intervention

Further Improve Results by Comparing Locomotives and Digging Deeper into Trends and Outlier Events
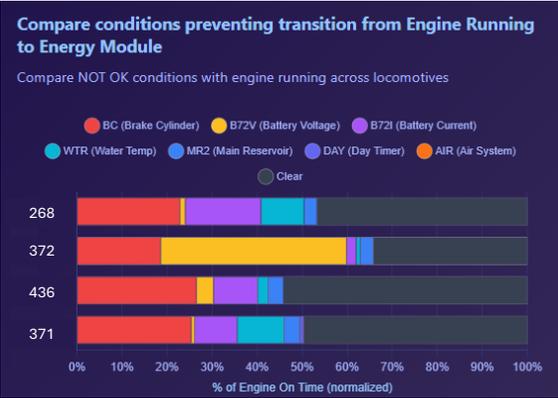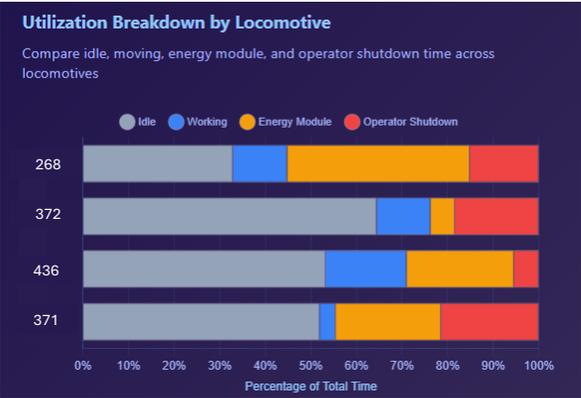
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Directly Compare Fuel Savings and GHG Reduction Across Your Fleet

Fuel Savings & Environmental Impact

Locomotive	Energy Module Time	Fuel Saved	Cost Savings	CO₂ Avoided
268	67d 17h 17m 51s	9589.3 gal	$29726.69	220,553 lbs
372	31d 21h 48m 23s	4518.3 gal	$14006.60	103,920 lbs
436	16d 15h 20m 45s	2356.1 gal	$7304.04	54,191 lbs
371	6d 17m 49s	851.4 gal	$2639.19	19,581 lbs
TOTAL	122d 6h 44m 48s	17315.0 gal	$53676.52	398,245 lbs

Usage Patterns can Show why Certain Locomotives Perform Better or Worse

Utilization Breakdown by Locomotive
Compare idle, moving, energy module, and operator shutdown time across locomotives

Legend: Idle, Working, Energy Module, Operator Shutdown

(Bar chart: 268, 372, 436, 371 — Percentage of Total Time, 0% to 100%)

Compare conditions preventing transition from Engine Running to Energy Module
Compare NOT OK conditions with engine running across locomotives

Legend: BC (Brake Cylinder), B72V (Battery Voltage), B72I (Battery Current), WTR (Water Temp), MR2 (Main Reservoir), DAY (Day Timer), AIR (Air System), Clear

(Bar chart: 268, 372, 436, 371 — % of Engine On Time (normalized), 0% to 100%)
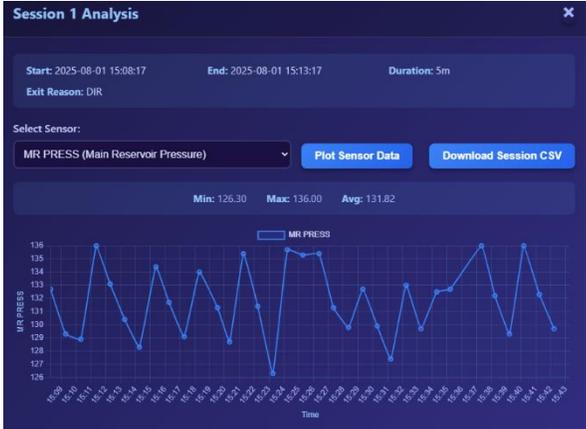
Keep Digging by Pulling Logs for Individual Sessions for a Locomotive

Energy Module Sessions
Sessions are defined as transitions into Energy Module and then transitions to any other mode. Total Sessions: **920**   Likely Override: **95**

#	Start Time	End Time	Duration	Exit Reason	Override?	Analyze
1	2025-08-01 15:08:17	2025-08-01 15:13:17	5m	DIR	⚠ Yes	Analyze
2	2025-08-04 18:41:15	2025-08-04 18:48:21	7m 6s	Engine Restarted (All OK)	-	Analyze
3	2025-08-04 19:27:20	2025-08-04 19:31:18	3m 58s	DIR	No	Analyze
4	2025-08-05 21:27:14	2025-08-05 21:27:14	0s	DIR	⚠ Yes	Analyze
5	2025-08-06 17:03:14	2025-08-06 17:05:14	2m	DIR	⚠ Yes	Analyze
6	2025-08-06 20:52:23	2025-08-06 21:23:16	30m 53s	DIR, TH	-	Analyze
7	2025-08-08 13:21:18	2025-08-08 13:21:18	0s	DIR	⚠ Yes	Analyze
8	2025-08-10 21:22:15	2025-08-10 22:59:19	1h 37m 4s	Disconnect	-	Analyze
9	2025-08-10 23:07:11	2025-08-10 23:11:12	4m 1s	Session still active at end of data	No	Analyze
10	2025-08-12 18:34:16	2025-08-12 18:35:18	1m 2s	DIR	No	Analyze

Showing 1-10 of 920   Next 10 →

Graph Sensor Readings to Look for Cause of Anomalous Events

Session 1 Analysis

Start: 2025-08-01 15:08:17   End: 2025-08-01 15:13:17   Duration: 5m
Exit Reason: DIR

Select Sensor:
MR PRESS (Main Reservoir Pressure)   [Plot Sensor Data]   [Download Session CSV]

Min: 126.30   Max: 136.00   Avg: 131.82

(Line chart: MR PRESS vs Time)

Remote Dashboard Provides Useful Information That Goes Beyond Idle Reduction Performance

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See Where A Locomotive Is/Has Been

Locomotive Location
Last known position from heartbeat data. Hover over markers to see city/state.

Greensboro, North Carolina

268 - NS 6088

Latitude: 37.279109	Longitude: -79.977281
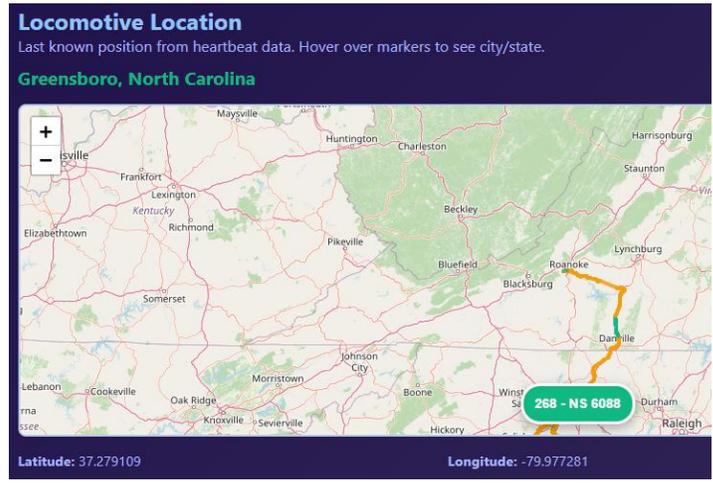
See How the Locomotive is Being Used

Locomotive Utilization Breakdown
Time breakdown: stationary, moving, energy module, and operator shutdown

Idle | Working | Energy Module | Operator Shutdown

Throttle Notch Usage
Time distribution across throttle notch positions

Energy Module | Idle | Notch 1 | Notch 2 | Notch 3 | Notch 4 | Notch 5
Notch 6 | Notch 7 | Notch 8

Total: **1477.0h**   Fuel Used: **7137 gal**   kWh: **65382 kWh**   Avg Notch: **0.5**

See Errors Recorded by the Train Control System

TECU Events

Critical	Warning	Total Types
● 1	● 3	📋 6

TECU (Throttle/Engine Control Unit) diagnostic messages reported by the locomotive. Events are sorted by severity (Critical > Warning > Info) then by frequency.

Severity	Message	Count	Days	Last Occurrence
● Critical	ENG STOP BY GOV LOS	3	1	1/6/2026, 10:17:16 AM
● Warning	ENG START LOADING DELAY	100	16	1/7/2026, 8:26:18 AM
● Warning	HIGH IDLE LOW WATER TEMP	5	1	12/29/2025, 10:28:14 AM
● Warning	MU 8T AND 9T HIGH	1	1	1/2/2026, 8:27:14 AM
○ Info	USE HDLT RESET FOR HVAC	16,057	17	1/7/2026, 5:59:12 PM

Working Sessions

Periods when the locomotive is actively doing work (Engine Running) + In Gear + Throttle Applied (MU NOTCH > 0). Sessions end when entering Energy Module, Operator Shutdown, Disconnect, or 30+ minutes without working activity.

Total Sessions: **252**   Total Working Time: **198h 39m**   Total Distance: **1887.6 km**

#	Start Time	End Time	Duration	Working Time	Work Output	Distance	Notch Range	Gear Changes	End Reason
1	2025-12-23 13:08:15	2025-12-23 14:47:24	1h 39m	1h 12m	170	26.5 km	1-6	17	Energy Module
2	2025-12-23 15:50:17	2025-12-23 19:07:17	3h 17m	2h 27m	209	41.4 km	1-6	41	Energy Module
3	2025-12-29 15:51:18	2025-12-29 21:20:17	5h 29m	4h 12m	490	68.9 km	1-7	57	Energy Module
4	2026-01-02 14:26:24	2026-01-02 21:42:21	7h 16m	5h 57m	864	121.5 km	1-8	83	Energy Module
5	2026-01-05 14:41:19	2026-01-05 19:16:15	4h 35m	3h 42m	405	65.0 km	1-7	75	Energy Module

A Real-World Return on Investment Example

Performance of a Locomotive with an ACS-RS IRT System* over a 60-day period extracted from the Remote Dashboard

Start Date: 12 / 22 / 2025
End Date: 02 / 19 / 2026
Reset to Full Range

Quick select: Last 7 Days | Last 30 Days | **Last 60 Days** | Last 90 Days
Diesel Price ($/gal): 3.10
Fuel Rate (gal/hr): 5.9
CO_2 (lbs/gal): 23

Fuel Savings & Environmental Impact

Energy Module Time	Fuel Saved	Cost Savings	CO_2 Avoided
29d 4h 8m 14s	4130.8 gal	$12805.51	95,009 lbs

Locomotive Timeline
Visual timeline showing AESS mode and movement status. Hold **Ctrl** (or

Select Range

2026-01-08 21:30:13 to 2026-01-09 10:11:13
☐ Energy Module - 12h 41m
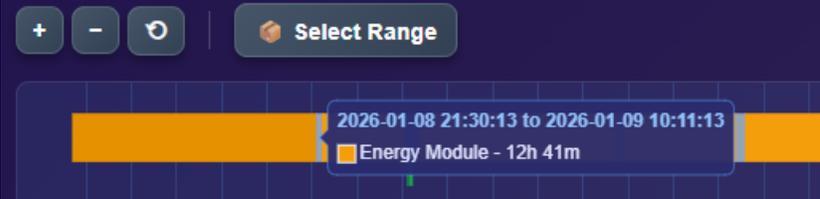
Energy Module Exit Reason Analysis
Conditions that caused the engine to restart

Legend: WTR | TH/DIR | All OK (Restart) | Disconnect | Operator Shutdown | BC | MR2 | B72V
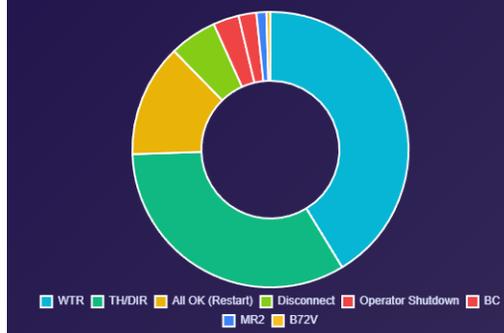
Over the course of a year, this would equate to:

- **24,784 gallons of fuel saved**
- **$ 77,830 in monetary savings** [1]
- **28.5 Tons of GHG Emissions avoided**

- **Investment payback < 2 years**
- **5 Year ROI ~ 233%**

1 Diesel Fuel Price and Fuel Burn Rate are User Settable

Even Further Savings May Be Possible

- **Proven sessions of the Energy Module being able to power locomotive systems for over 12 hours at a time**

- **During this 60-day period there were no incidents of the Locomotive leaving "AESS mode" due to the Energy Module discharging past its limits**

* The ACS-RS IRT system used in this example was an first generation version that did not crank the engine and offered only 33 kWh of battery power

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- **Potential for $100K a year in Fuel Savings per Locomotive**

- **Potential for 30 Tons a year of GHG emission avoidance per Locomotive**

- **Minimized possibility of a stranded train due to a battery failure**

- **Keep your crews safe and comfortable**

- **Increase efficiency and validate program results with insightful remote data**

- **Improve competitiveness vs. other forms of shipping**

- **Keep relevant stakeholders satisfied because sustainability is good business**