



HY-Ranger

Cleaner Combustion at the Source

Evidence-backed hydrogen-assisted combustion for
rail, fleets, mining, construction, and stationary
engines

MANSOUR RAIL FULL-LOAD TEST

LYNX MULTI-ASSET FIELD TESTS

Prepared for customers evaluating cleaner combustion, lower soot/PM, fuel savings,
and operating value from existing assets

August 2026

HYGN

ns Test Report

series of e-test reports
K Emissions, on behalf of HYGN
customers who are currently using
e report showcases emission
the installation of the HY-Ranger

the following vehicle types:

quipment





Executive message

Two product-specific evidence cornerstones support a PM/soot-first customer story.

AT A GLANCE

HYGN targets incomplete combustion before exhaust reaches filters, catalysts, SCR, DPF, mufflers, or mine ventilation.

12.5%

Diesel fuel reduction

Mansour: four-hour sustained full-load rail test

95%

Opacity reduction

Mansour: visual smoke reduction; not mass-PM

63.6%

Average reported PM reduction

Lynx: simple average across 9 reported test points



The strongest customer proposition is not a universal promise. It is a repeatable pathway: improve combustion, measure PM/soot and fuel under matched conditions, then scale from verified results.

MEASURED ON TESTED ASSETS

SUPPORTED BY PEER-REVIEWED RESEARCH

The problem: fuel-rich pockets become soot, PM, and operating cost

Incomplete combustion is an emissions problem and an asset-management problem.

WHY IT MATTERS



Incomplete burn

Poor mixing, transient load, deposits, cold operation, and fuel-rich zones leave CO, HC, smoke, and unburned carbon.



Soot / PM formation

Carbonaceous particles form where local fuel and oxygen are not mixed or oxidized completely.



Aftertreatment burden

More engine-out soot means greater filter loading, backpressure, regeneration demand, and exhaust restriction.



Downtime and cost

Derates, service calls, cleaning, lost production, fuel waste, and visible smoke turn emissions into operating expense.

HYGN's approach is source reduction: change the combustion event first, then reduce the burden placed on downstream controls.



How HY-Ranger works

A small, controlled on-demand H_2/O_2 flow supports the combustion of the fuel the engine already uses.

COMBUSTION PATHWAY



What HY-Ranger is not

- Not a full hydrogen conversion
- Does not replace the primary gasoline or diesel fuel
- Does not require high-pressure hydrogen storage
- Designed for existing assets and asset-specific validation

Emissions Test Report

The following are a series of e-test reports conducted by LYNX Emissions, on behalf of HYGN and their various customers who are currently using the HY-Ranger. The report showcases emission levels pre and post the installation of the HY-Ranger Hybrid Kit.

The report covers the following vehicle types:

- Pick-up Trucks
- Mining Vehicles
- Construction Equipment
- Buses



On-demand generation • engine intake integration • no high-pressure storage



What makes HYGN unique

A rugged single-cell Nickel-200 alkaline electrolyzer designed for mobile and industrial retrofit duty.

PRODUCT DIFFERENTIATION



Simple electrical path

Single-cell architecture avoids a large multi-cell stack and is designed for low-voltage, current-controlled operation. Efficiency is verified from gas output per



Built for alkaline duty

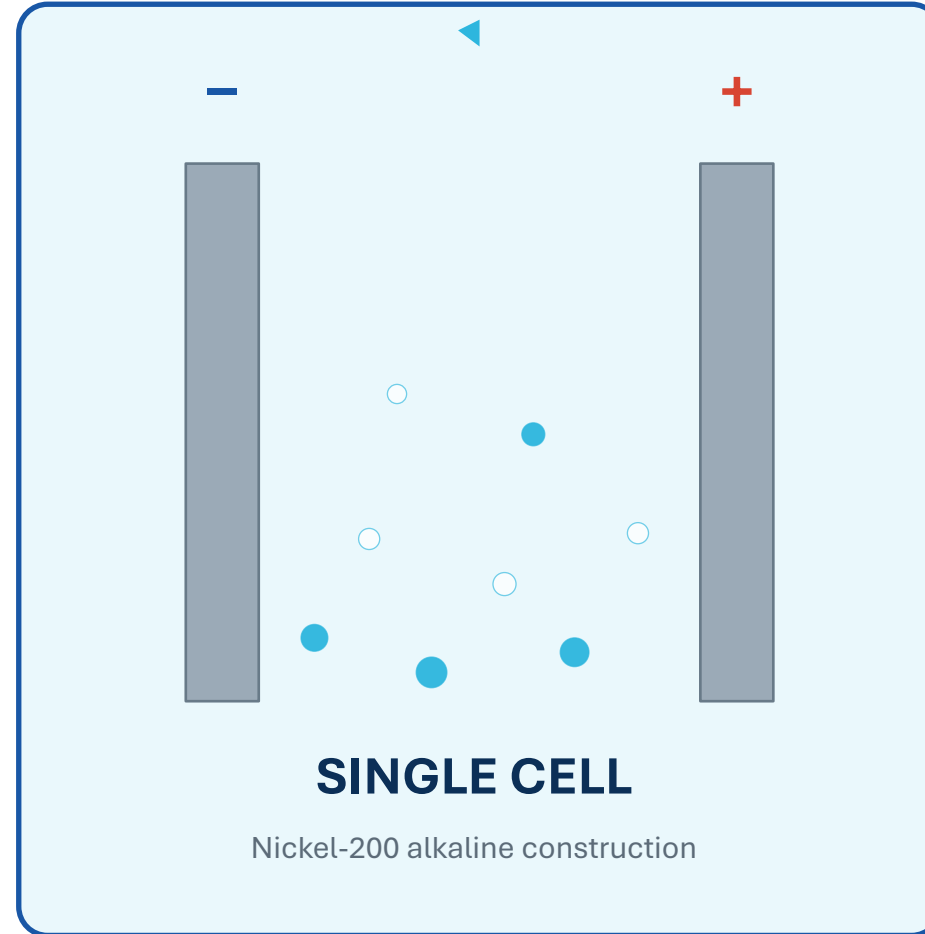
Nickel-200 is commercially pure nickel with strong resistance in many alkaline media, high ductility, and high electrical conductivity.



Long-service potential

A rugged metal cell, controlled current, water quality, and sensor interlocks support service life. Actual lifetime remains duty- and maintenance-dependent.

Controlled gas outlet



On demand and low pressure

Hydrogen is produced only while the system is operating. The architecture does not rely on high-pressure hydrogen storage.



Active safety controls

HYGN documents temperature, pressure, moisture, and shutdown logic. Commercial installations still require engine- and site-specific



Recyclable material value

Nickel-containing components can be recovered at end of life; nickel has one of the highest recycling efficiencies among engineering metals.



The evidence framework

Product-specific results lead; academic research explains mechanism and operating limits.

FOUR LAYERS

1 MANSOUR RAIL — controlled full-load test

Four-hour, sustained full-load test on a high-horsepower 2-stroke diesel engine. Fuel, NO, NO₂, CO₂, and opacity were compared with the established baseline.

2 LYNX EMISSIONS — third-party multi-asset field evidence

Customer vehicles across gasoline and diesel pickups, buses, utility, construction, concrete, dump, and Class 8 platforms.

3 PEER-REVIEWED RESEARCH — mechanism and boundaries

Canadian, U.S., Australian, and international studies support hydrogen-assisted combustion while showing the importance of load, oxygen, timing, boost, EGR, and H₂ rate.

4 CUSTOMER VALIDATION — business case on the real duty cycle

Matched fuel, useful work, electrolyzer power, emissions, aftertreatment, maintenance, and uptime data determine whether to scale.

Evidence language used throughout the deck

MEASURED

SUPPORTED

OBSERVED

VALIDATE



CORNERSTONE 1

Mansour Rail: full-load validation on a 2-stroke diesel engine

The first cornerstone is a controlled four-hour test under sustained full load — the operating condition that matters most for high-horsepower rail economics and visible exhaust.

4 h

sustained full-load test

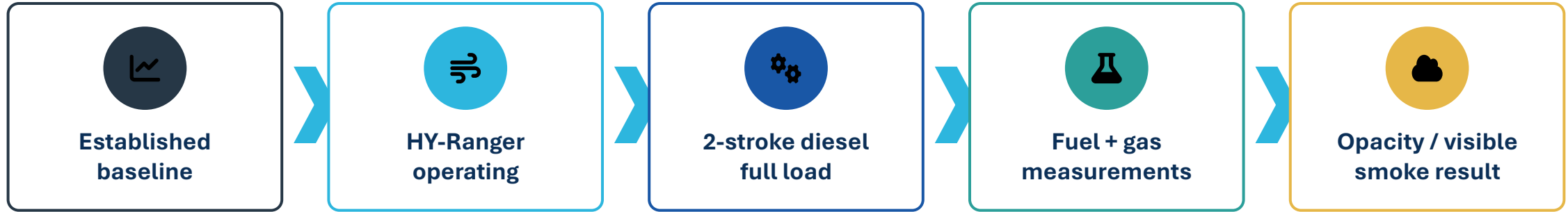
1,800 hpengine rating stated in
title/opening**2-stroke**high-horsepower diesel
platform



Mansour test methodology and setup

What the testimonial documents — and what a formal technical report should add.

DOCUMENTED TEST DESIGN



Documented in the Mansour testimonial

- Controlled four-hour test
- Sustained full-load operation
- Demanding condition representative of intended application
- HY-Ranger-on comparison with established baseline
- Measured diesel use, NO, NO₂, CO₂, and opacity

For formal publication, add

- Fuel-metering method and baseline duration
- Analyzer models, calibration, sampling point, units, and raw readings
- Exact engine model / nameplate horsepower
- Opacity method and repeat-run variability
- Exhaust flow or work-normalized emissions where possible

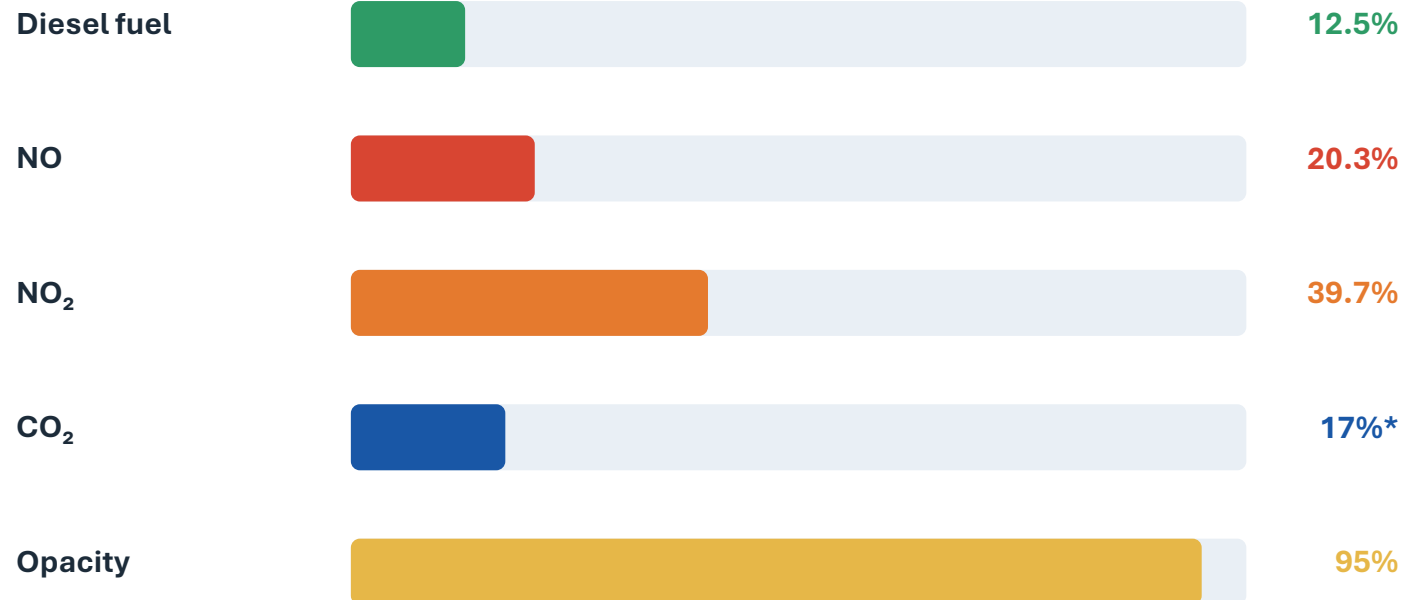


Mansour full-load results

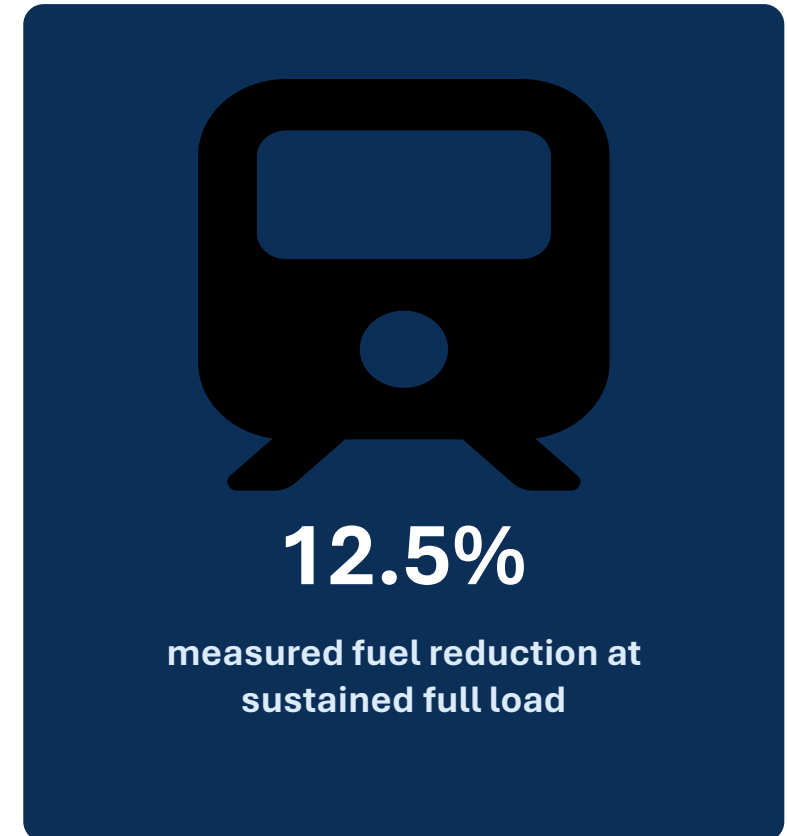
Measured during the initial four-hour test with HY-Ranger operating versus the established baseline.

RESULTS

Full-load change with HY-Ranger



* Approximately 17% CO₂ reduction; the testimonial describes this as directionally consistent with lower diesel consumption.



Mansour expects further improvement through a break-in / conditioning period; that expectation was not yet measured in the initial four-hour result.

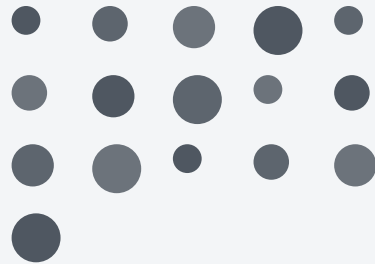


Why the 95% opacity reduction matters

Opacity is a visible-smoke indicator — a powerful operational signal, but not a substitute for mass-PM measurement.

PM / SOOT FOCUS

BASELINE



HY-RANGER ON



95% reported visual reduction



Strong evidence of less visible smoke

A major opacity decrease is consistent with a large change in soot-related exhaust appearance during the reported test.



Not the same as gravimetric PM

Opacity measures light obstruction by exhaust. Particle mass, elemental carbon, and particle number require dedicated sampling.



Next rail test package

Add filter-based PM mass, elemental carbon, particle number, exhaust flow, repeat runs, and notch-by-notch/load-point results.

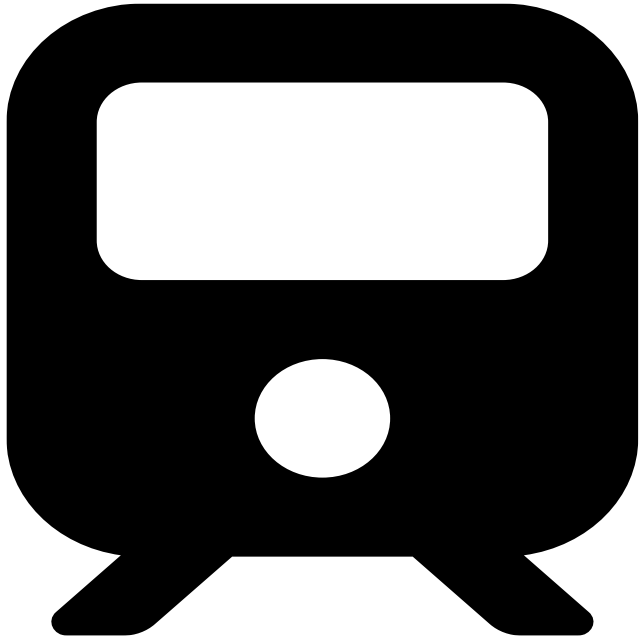
Independent diesel studies report reduced smoke/soot under suitable hydrogen rates and air-management conditions — while also showing that full-load oxygen availability must be managed.



Rail and high-horsepower two-stroke customer case

Preserve the locomotive asset while targeting fuel, smoke, yard visibility, and emissions.

RAIL VALUE



Why rail is a strong fit

- Very high fuel burn and long operating life
- Older two-stroke engines can remain productive for years
- Visible smoke affects yards, communities, workers, and customer perception
- Large asset value makes retrofit economics compelling
- Full-load results directly address the most demanding operating point

Recommended next phase

- Repeat at multiple load / notch points
- Direct fuel flow and useful output
- NO, NO₂, CO, CO₂, O₂, opacity and mass PM
- Exhaust temperature and cylinder / engine limits
- Durability and maintenance over operating hours
- Independent test report suitable for customer and regulatory review

Mansour states that the initial result provided confidence to become DHT's rail-industry installation partner.

YGN

Emissions Test Report

RANGER



CORNERSTONE 2

Lynx Emissions: third-party field testing across real customer assets

The report compares emissions before and after HY-Ranger installation across pickups, mining vehicles, construction equipment, buses, Class 8 trucks, utility trucks, snowplows, and garbage trucks.

19 CO TEST POINTS

13 NOx TEST POINTS

9 PM TEST POINTS

Source: Lynx Emissions, HY-Ranger Emissions Test Report, 2025.



Lynx testing: introduction, methodology, and setup

A multi-asset field comparison — useful product evidence, but not a standardized certification test.

AS DOCUMENTED



Emissions Test Report

The following are a series of e-test reports conducted by LYNX Emissions, on behalf of HYGN and their various customers who are currently using the HY-Ranger. The report showcases emission levels pre and post the installation of the HY-Ranger Hybrid Kit.

The report covers the following vehicle types:

- Pick-up Trucks
- Mining Vehicles
- Construction Equipment
- Buses
- Class-8 Trucks
- Utility Trucks
- Snow plow
- Garbage Trucks



Purpose

Compare emissions before and after installation of the HY-Ranger Hybrid Kit.

Assets

Customer-owned gasoline and diesel vehicles across eight vehicle/equipment categories.

Metrics

CO, NOx and PM/opacity results are reported depending on the specific asset.

Output

Vehicle-by-vehicle percentage-reduction pages with asset description and result graphics.

Strength

Broad application diversity and product-specific pre/post evidence.

Limitation

The summary report does not provide complete analyzer calibration, repeat-run, exhaust-flow, or mass-normalized test-cycle detail.

Best use of the Lynx report: product-specific evidence that justifies controlled, repeated, asset-specific validation and larger demonstration programs.



Lynx aggregate pattern across reported test points

Simple averages of the percentage-reduction values shown in the report.

AGGREGATE PATTERN

CO



72.8%

19 test points

NOx



63.8%

13 test points

PM



63.6%

9 test points

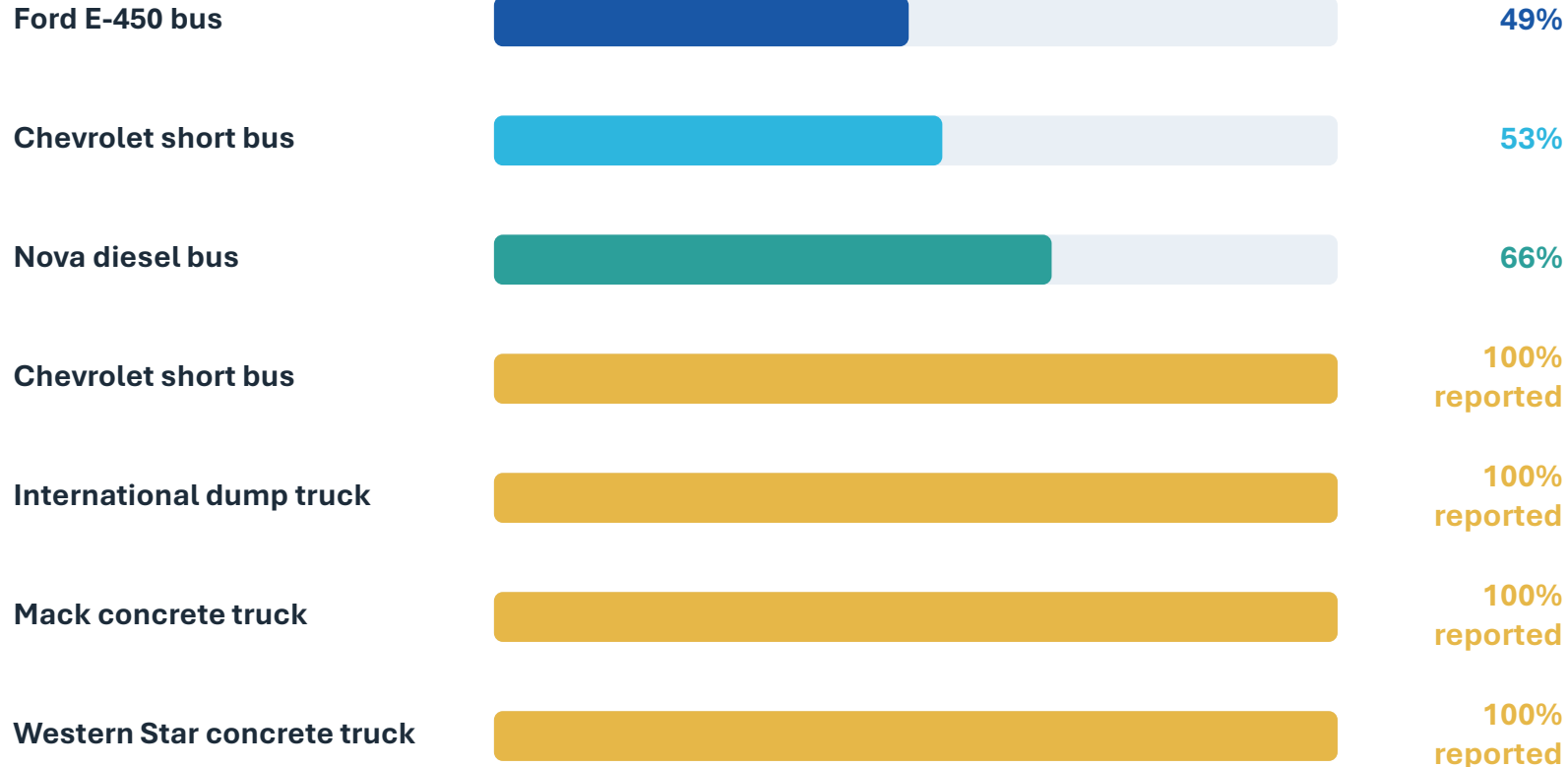
Interpretation: these are unweighted averages of reported percentage reductions — not fleet-weighted, mass-weighted, or regulatory-cycle averages.



Lynx PM / soot results across buses and heavy vocational assets

Multiple customer platforms reported large PM reductions after HY-Ranger installation.

PM RESULTS



49–100%

reported PM reduction
range across the selected
Lynx examples

“100% reported” means the post-test
result reached the report’s stated
threshold or output — not that every
particle was eliminated.



Lynx heavy-duty evidence: three customer examples

Bus, dump truck, and concrete truck results show the breadth of the reported PM/soot signal.

VEHICLE EXAMPLES

HYGN Emissions Test

HY-RANGER

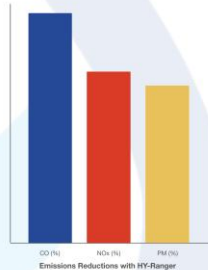
Vehicle Type: City Bus
Make: Nova
Model: Long Bus
Engine Type: 9L Diesel
Year: 2016



99%
CO%
REDUCTION

73%
NOx%
REDUCTION

66%
PM%
REDUCTION



9 L diesel bus

99% CO • 73% NOx • 66% PM

HYGN Emissions Test

HY-RANGER

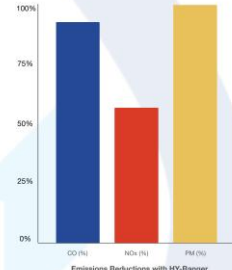
Vehicle Type: Dump Truck
Make: International
Model: HV Series
Engine Type: 12.4L Diesel
Year: 2020



92%
CO%
REDUCTION

54%
NOx%
REDUCTION

100%
PM%
REDUCTION



12.4 L diesel dump truck

92% CO • 54% NOx • 100% reported PM

HYGN Emissions Test

HY-RANGER

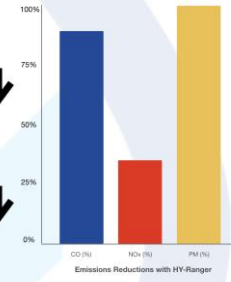
Vehicle Type: Concrete-Truck
Make: Western Star
Engine Type: 13L Diesel
Year: 2020



88%
CO%
REDUCTION

31%
NOx%
REDUCTION

100%
PM%
REDUCTION



13 L diesel concrete truck

88% CO • 31% NOx • 100% reported PM

These are product-specific field results on the tested assets. They support broader validation; they do not guarantee identical percentages on another engine or duty cycle.



Canadian academic support: references 7–10

Independent studies validate the mechanism — and define the controls needed to protect PM/soot performance.

PEER-REVIEWED EVIDENCE

[7]

NRC Canada — diesel HCCI

Hydrogen shortened combustion duration, improved stability, increased fuel conversion efficiency, and reduced specific CO and overall HC.

Supports faster, more stable combustion and lower incomplete-combustion pollutants.

[8]

UBC — commercial Class 8 truck

Pre-manifold hydrogen retrofit achieved 10–30% CO₂ reduction across loads. At high load, CO and soot increased when boost and oxygen availability fell.

Supports retrofit feasibility — and the need to protect air supply at high load.

[9]

SAE on-road Canadian truck data

Real-road testing found tailpipe CO₂ reductions correlated with hydrogen substitution and lower exhaust NO_x than the neat-diesel baseline.

Supports on-road evidence and direct measurement on real duty cycles.

[10]

NRC heavy-duty engine controls

Coordinated boost, timing and EGR enabled 40% H₂ energy share with 40% CO₂ reduction and 55% PM reduction without increasing NO_x versus diesel.

Shows that controls — not hydrogen alone — determine the strongest PM/NO_x outcome.



Independent PM / soot evidence beyond HYGN and Lynx

The literature repeatedly reports smoke or PM reductions — with clear load, oxygen, injection, and control conditions.

LITERATURE SIGNAL

1983 Varde & Frame

~10% H₂ energy substantially reduced smoke at part load; full-load benefit was limited by excess-air availability.

2010 Bari & Esmaeil

On-board electrolysis H₂/O₂ testing reported improved thermal efficiency in a conventional diesel engine.

2010 Saravanan & Nagarajan

Smoke was lower across the tested load range under optimized port injection; NO_x was slightly higher at full load.

2025 Farzam et al.

Coordinated boost, timing and EGR delivered 55% PM reduction at high H₂ share with no NO_x increase versus diesel.

Literature consensus: hydrogen can reduce smoke/soot/PM under suitable conditions. Boundary condition: insufficient oxygen, poor calibration, or excessive H₂ can weaken or reverse the result.



Why PM / soot reduction creates customer value

Source reduction can create health, maintenance, uptime, and community benefits before exhaust reaches downstream controls.

VALUE STACK



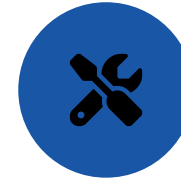
Worker and public health

Diesel exhaust is classified as carcinogenic to humans. Underground and diesel-intensive workplaces can face elevated exposure.



Aftertreatment burden

Less engine-out soot can reduce the material presented to DPFs, catalysts, mufflers, and filtration systems.



Maintenance and uptime

Potential value includes lower backpressure, fewer regenerations, fewer derates, cleaner components, and longer service intervals — when verified.



Site and community impact

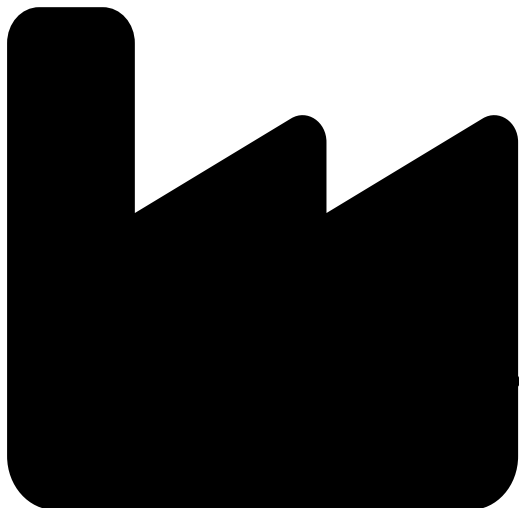
Lower visible smoke can improve yard, municipal, construction, mine, and community operating conditions.

Important: HY-Ranger can be a source-control measure; it does not replace required ventilation, aftertreatment, exposure monitoring, maintenance, or regulatory controls.

Customer use case: stationary generators, oil & gas, and remote industrial power

Fixed or repeating loads create one of the clearest paths to a defensible fuel-and-emissions business case.

STATIONARY & REMOTE



Why it fits

- High annual fuel spend and long engine hours
- Repeatable load points and easier direct fuel metering
- Soot, wet-stacking, deposits, and low-load exhaust issues
- Remote service calls and downtime are expensive
- Useful output can be measured directly in kWh, pumping, or production

What to measure

Fuel flow	L/h or kg/h at matched load
Output	kWh, pumping, compression or process output
Electrolyzer	V, A, duty cycle, kWh and gas output
Emissions	CO, NOx, O ₂ , CO ₂ , opacity and PM
Condition	Exhaust temperature, oil soot, deposits, service events

Best proof metric: total measured energy input per unit of useful output — with electrolyzer electrical input included.



Customer use case: Class 8, vocational, construction, and concrete fleets

High fuel burn, high utilization, visible smoke, and expensive downtime make heavy assets a priority.

HEAVY-DUTY FLEETS



Customer priorities

- Fuel cost per mile, hour, or tonne moved
- DPF/SCR regeneration, derates, and roadside/site service
- Smoke and soot under load, idle, and PTO operation
- Long remaining asset life and slow replacement cycles
- Route, payload, and operator variability

Product-specific evidence

Dump truck PM		100% reported
Dump truck CO		92%
Concrete PM		100% reported
Concrete CO		88%

Canadian truck research confirms retrofit feasibility and shows that boost, oxygen, timing, and EGR must be controlled — especially at high load.

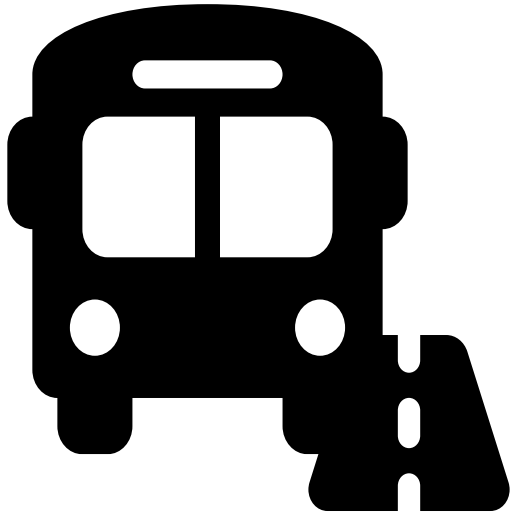
Pilot design: 6–8 weeks of baseline + matched routes or duty bins + direct/validated fuel data + DPF/regen/fault logs + repeat emissions testing.



Customer use case: municipal, transit, and utility fleets

Stop-start duty, idling, PTO, public visibility, and long ownership cycles create a measurable retrofit opportunity.

PUBLIC FLEETS

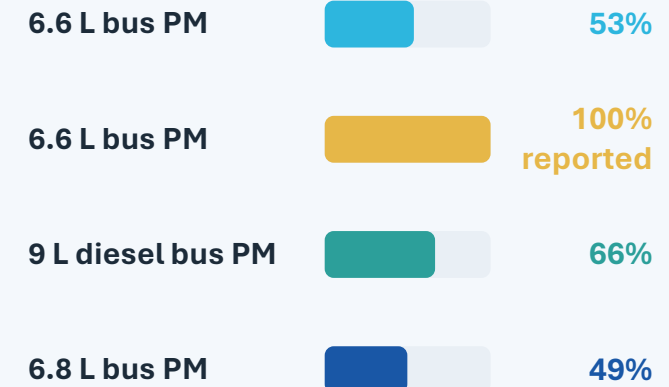


Why these fleets are attractive

- High idle and stop-start operation
- Low exhaust temperature and soot-management challenges
- Fuel-card, telematics, route, work-order, and maintenance data already exist
- Public accountability and visible smoke matter
- Representative pilots can be run without disrupting service

Municipal proof is strongest when emissions results are paired with real route-normalized fuel and maintenance records.

Lynx bus examples



Match route, operator, payload, season, idle/PTO, warm-up, and aftertreatment state before comparing results.



Customer use case: underground mining

PM / DPM reduction has direct relevance to worker exposure, ventilation load, filter burden, and production.

UNDERGROUND PRIORITY



Mine-operator value

- Lower tailpipe PM / elemental carbon where verified
- Lower CO and NOx on the actual machine and duty cycle
- Potentially slower filter loading and lower exhaust restriction
- Cleaner visibility and working conditions
- Potential ventilation and maintenance value — only after engineering validation

HY-Ranger complements — not replaces — ventilation, maintenance, monitoring, filtration, and required mine controls.

What to measure underground

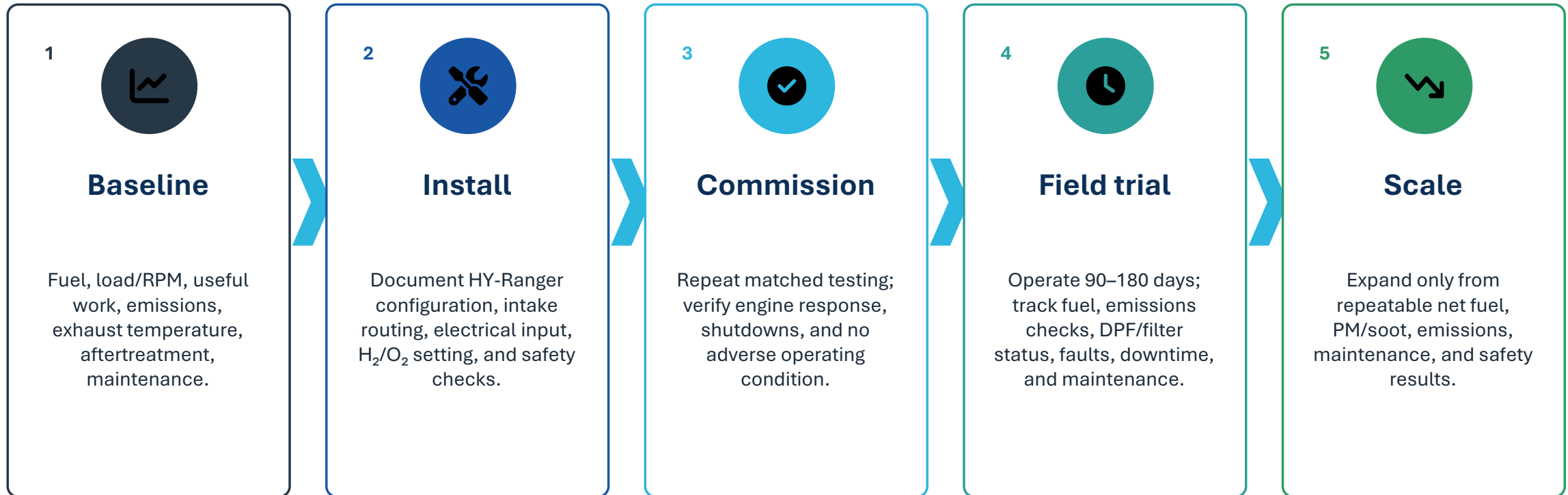
- Tailpipe PM / EC, CO, NOx and opacity
- Personal and ambient exposure
- Ventilation rate and contaminant load
- Engine heat and exhaust temperature
- Filter loading and maintenance
- Fuel and productive engine hours



Measurement-led deployment: from pilot to fleet scale

A defensible rollout turns product evidence into customer-specific operating value.

RECOMMENDED PROGRAM



Primary decision metrics

Net fuel / useful output • PM / soot / opacity • CO and NO_x • electrolyzer kWh • DPF / filter loading • uptime and maintenance • safety performance



**Keep the asset.
Improve combustion.
Reduce soot and PM.
Measure the value.**

**Mansour full-load rail evidence + Lynx multi-asset
testing + peer-reviewed research + customer-
specific validation**

Key references

- [M] Mansour. HY-Ranger Rail Edition Load Test Testimonial.
- [1] Lynx Emissions. HY-Ranger Emissions Test Report. 2025.
- [7] Guo et al. Int J Hydrogen Energy. 2011.
- [8] Guan et al. Int J Hydrogen Energy. 2024.
- [9] Kheirkhah et al. SAE 2023-01-0281.
- [10] Farzam et al. Int J Hydrogen Energy. 2025.
- [15] Varde & Frame. Int J Hydrogen Energy. 1983.
- [20] Bari & Mohammad Esmaeil. Fuel. 2010.
- [28] Saravanan & Nagarajan. Applied Energy. 2010.
- [35-41] IARC, NIOSH, Health Canada, EPA, Safe Work Australia.

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Product-specific results vary by engine, duty cycle, condition, hydrogen rate, installation, calibration, and test method.