Square Robot Inc.
12302 FM 529 Suite 1
Houston, TX 77041

WHITE PAPER

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How Square Robot's In-Service Tank Inspection Technology Eliminates Greenhouse Gas Emissions from the Tank Inspection Process

squarerobot.com · 2026

1,087	Zero	5
Tonnes CO_2e Contained	**Tank Pumpouts Required**	**Fuel Types Modeled**
Cumulative avoided emissions across all Square Robot inspections	*Tank remains in service — no venting, no cleaning, no emissions event*	*Diesel, kerosene, jet fuel, gasoline, and naphtha*

EXECUTIVE SUMMARY

Every time an aboveground storage tank undergoes conventional inspection, hundreds to thousands of kilograms of hydrocarbon vapor are released into the atmosphere. These emissions are not an accident — they are an unavoidable byproduct of the manual inspection process, which demands that operators drain, vent, and clean each tank before a human inspector can enter.

Square Robot eliminates this emissions event entirely. By deploying autonomous robotic inspection technology that operates inside tanks while they remain filled and in service, Square Robot removes the need for pumpout, venting, and confined-space entry — and with it, the associated greenhouse gas releases.

This white paper explains the mechanism by which conventional inspections generate emissions, the model used to quantify those emissions, and the documented impact of Square Robot's approach. It is intended for ESG and sustainability teams evaluating storage tank inspection practices as part of their emissions reduction strategy.

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To date, Square Robot has contained 1,087 tonnes of CO_2e across its inspection portfolio — emissions that would have been released had those tanks undergone conventional inspection.

This figure is calculated using a peer-reviewed emissions model developed by Positive Scenarios Consulting, LLC, based on U.S. EPA AP-42 methodology and validated against project-specific tank parameters.

THE EMISSIONS PROBLEM WITH CONVENTIONAL TANK INSPECTION

Aboveground storage tanks are required by regulation to undergo periodic internal inspection — typically every 10 to 30 years depending on tank type, condition, and jurisdictional requirements. The purpose of these inspections is to assess corrosion and structural integrity of the tank bottom before a failure can occur.

Under the conventional inspection process, operators have no choice but to take the tank fully out of service. The sequence of activities required generates emissions at three distinct stages:

Stage 1: Pumpout

The stored liquid is pumped out of the tank over a period of days to weeks. For floating-roof tanks, as the liquid level drops and the roof lands on its legs, a new vapor space is created above the remaining liquid heel. This vapor space — which does not exist under normal operating conditions — allows volatile hydrocarbons to evaporate and escape. The quantity of these “standing idle losses” depends on ambient temperature variation, tank geometry, and the vapor pressure of the stored product.

Stage 2: Venting

Once the tank is emptied, residual volatile vapors must be purged before personnel can enter. Forced ventilation using fans and blowers expels these vapors directly to atmosphere. This is the single largest emissions stage in the conventional process. Any remaining liquid — pooled in sumps, clinging to interior surfaces, or mixed with bottom sediment — continues to evaporate throughout ventilation and cleaning, adding to the total release. Venting typically continues for 24–48 hours before entry is safe, and often throughout the cleaning process as well.

Stage 3: Refilling

When the tank is returned to service and refilled, the incoming liquid displaces vapor upward through open vents as the liquid level rises. Both fixed-roof and floating-roof tanks release vapors during refilling, though the quantity differs by tank type and the height of the vapor space that must be displaced.

The venting stage alone can release tens of thousands of pounds of hydrocarbon vapor per inspection event — vapor that ultimately oxidizes to CO_2 in the atmosphere.

These vapors consist primarily of non-methane volatile organic compounds (NMVOCs). While NMVOCs do not have a direct global warming potential equivalent to methane, they contribute to atmospheric warming through two pathways: intermediate atmospheric reactions that form ozone and other warming agents, and the ultimate oxidation of hydrocarbon chains to carbon dioxide. Square Robot's emissions model accounts for the CO_2 conversion pathway, which is the more conservative and scientifically accepted approach for quantifying the GHG impact of these releases.

HOW SQUARE ROBOT ELIMINATES THE EMISSIONS EVENT

Square Robot's autonomous inspection robots are deployed into tanks while they remain in service — filled with product, at operating temperature and pressure, with no interruption to throughput. The robot navigates the tank floor using a pre-programmed path, collecting phased array ultrasonic testing (PAUT) data that maps remaining wall thickness across the entire tank bottom.

Square Robot offers two deployment methods — roof entry and shell-side entry via Square Robot's proprietary Side Launch System — each designed to minimize or entirely eliminate the emissions associated with tank access. The deployment approach is selected based on tank configuration, product level, and operator preference.

Roof Entry Deployment

For roof entry, a roof manway is opened briefly to lower the robot into the tank and retrieve it at the end of each inspection day. The tank remains full and in-service throughout. The only emissions-relevant activities are:

- Momentary opening of a roof manway to lower and retrieve the robot — negligible vapor release given the brief duration and small aperture
- Evaporation of trace product clinging to the robot on retrieval — minimal and considered negligible in the emissions model
- Generator fuel combustion for crew trailer power and robot battery charging — a minor fraction of total project emissions

Square Robot's Side Launch System — Three Deployment Scenarios

Square Robot's Side Launch System accesses the tank through a shell manway using a manway adapter and gate valve assembly, offering operators three deployment scenarios with different emissions profiles depending on site conditions and operational timing:

Scenario 1: Hot Tap Installation — Zero Emissions

The manway adapter and gate valve are installed directly onto the tank shell via hot tap while the tank remains fully in service at normal operating product levels. The tank is never taken out of service, product levels are never adjusted, and no vapor space is created at any point. This scenario eliminates emissions entirely — there is no pumpout event, no venting event, and no refilling event associated with the inspection. It represents the strongest possible emissions avoidance case.

Scenario 2: Pre-Installation During Planned Low-Level Operations — No Incremental Emissions

When a tank's product level is already low due to normal operational cycles — such as a scheduled draw-down or routine throughput — the manway adapter and gate valve can be installed at that time in advance of the inspection. Because the product level reduction occurs as part of normal operations rather than as an inspection-driven pumpout, no incremental emissions are attributable to the inspection process. When the robot inspection is subsequently conducted, the tank is back in-service with no operational disruption.

Scenario 3: Partial Drain to Shell Manway Height — Significantly Reduced Emissions

Where hot tapping is not feasible and pre-installation is not possible, the operator drains the product level only to just below the shell manway — a fraction of the total tank volume — to allow installation of a manway adapter and gate valve. This is fundamentally different from a conventional inspection pumpout, which requires complete tank drainage. The partial draw-down generates a much smaller vapor space and proportionally lower pumpout losses, significantly reducing emissions compared to a full conventional inspection event. Critically, the venting stage — the largest single emissions source in conventional inspection — is still completely eliminated, as confined-space entry is never required. Once the adapter and gate valve are installed, the tank can be refilled to normal operating levels before or during the inspection, and the robot operates with the tank in service.

> In all three Side Launch scenarios, the venting stage — the largest single source of emissions in a conventional inspection — is completely eliminated. There is no confined-space entry, no forced vapor purge, and no full tank refilling event.

The following table summarizes the key differences between conventional inspection and Square Robot's in-service approach from an emissions perspective:

CONVENTIONAL INSPECTION	SQUARE ROBOT IN-SERVICE INSPECTION
Tank must be fully drained (days to weeks)	**Tank remains in service — roof entry, hot tap, or partial drain only to shell manway height**
Vapor space created during full roof landing generates pumpout losses	**No full pumpout — vapor space eliminated or minimized depending on deployment method**
Forced ventilation releases all residual vapors to atmosphere	**No venting required — zero venting emissions in all deployment scenarios**
24–48+ hours of continuous vapor purging before safe entry	**Inspection crew never enters tank**
Refilling displaces tank vapor through open vents	**No full refilling event in roof entry or hot tap scenarios**
Sediment and sludge removed as hazardous waste	**No tank cleaning required**
Total inspection downtime: weeks to months	**Typical inspection: days in-tank vs weeks or months**
Emissions model scope: pumpout + venting + refilling	**Emissions model scope: minor trace sources only**

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THE AVOIDED EMISSIONS MODEL

Square Robot quantifies the emissions avoided on each inspection project using a model developed by Positive Scenarios Consulting, LLC (PSC). The model was first developed in 2022 and updated in 2026 to expand coverage to gasoline and naphtha in addition to the original fuels (diesel, kerosene, and jet fuel A). The model is based on established U.S. EPA AP-42 methodology, Chapter 7: Liquid Storage Tanks, and is applied on a per-project basis using project-specific inputs.

Methodology Foundation

The core of the model estimates total hydrocarbon vapor release during each emissions stage of the conventional inspection process, using tank geometry, fuel properties, and ambient conditions as inputs. Emissions calculations follow AP-42 equations for:

- Standing idle losses during roof landing (pumpout phase)
- Wind-induced vapor loss for external floating-roof tanks
- Residual liquid volatilization during venting and cleaning (ventilation phase)
- Working losses and filling losses during tank refilling (refilling phase)

The global warming potential (GWP) of released vapors is then calculated based on the mass percentage of carbon in the vapor, converted to CO_2 equivalents using the oxidation pathway (44/12 carbon-to-CO_2 conversion factor). This approach, consistent with IPCC and peer-reviewed literature, provides a conservative estimate of GHG impact by focusing on the CO_2 pathway while excluding more uncertain intermediate atmospheric reactions.

Model Boundary and Conservatism

The model intentionally excludes several emission sources that would likely increase the calculated avoided emissions if included, such as upstream equipment manufacturing, transportation, cleaning activities, and repair operations. The conservative boundary ensures that all reported emissions avoidance figures are defensible and grounded in established methodology rather than theoretical estimates.

The model is considered conservative and likely underestimates actual lifecycle GHG savings. Excluded stages — particularly waste handling, cleaning operations, and the additional emissions from repair activities triggered by inspection findings — would all add to the baseline scenario emissions if evaluated.

Fuel Coverage

As of 2026, the model covers the following fuel types, reflecting the full range of Square Robot's current operations:

Fuel Type	RVP Range (psi)	GHG Impact Range (tCO_2e)	Notes
Diesel	< 1.0	3 – 8	Lower volatility; widely stored
Kerosene / Jet Fuel A	< 1.0	2 – 6	Aviation and heating applications
Gasoline – Hot Weather Blend	6 – 8	4 – 7	Summer / ozone-season blend

Gasoline – Standard Blend	9 – 11	5 – 8	Year-round reference blend
Gasoline – Cold Weather Blend	12 – 14	6 – 10	Winter blend; highest volatility
Naphtha – Heavy	2.5 – 4.5	3 – 6	Petrochemical feedstock
Naphtha – Straight/Standard	5 – 7	4 – 7	Reforming feedstock
Naphtha – Light Blends	7.5 – 14	5 – 11	Highest emission potential

Table 1. Fuel types covered by the Square Robot Avoided Emissions Model v1.2, with representative GHG impact ranges for a 100-ft diameter internal floating-roof tank.

Key Input Parameters

For each inspection project, Square Robot collects the following inputs to run the model:

- Tank diameter, height, and roof type (fixed, internal floating, external floating)
- Roof landing leg height and dome/cone configuration
- Stored fuel type and, where known, Reid Vapor Pressure (RVP)
- Liquid level at time of inspection
- Average ambient and daily temperature range during the project
- Presence or absence of vapor control or recovery systems
- Average sediment/sludge depth observed during inspection (informs venting calculations)

DOCUMENTED IMPACT

Across Square Robot's full inspection portfolio, the avoided emissions model has been applied on a per-project basis to estimate the greenhouse gas impact of each inspection. The aggregate result to date represents a meaningful and measurable climate contribution:

1,087 **Tonnes CO_2e Contained** *Total avoided emissions across all projects*	**60–150 ft** **Typical Tank Diameter** *Project range covered by the model*

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These figures represent only the emissions directly attributable to the pumpout, venting, and refilling stages avoided through Square Robot's technology. They do not include the avoided waste handling, cleaning, transportation, or repair-related emissions that would be included in a full lifecycle assessment — meaning the true climate benefit is likely higher.

For ESG reporting purposes, these avoided emissions can be classified as Scope 1 emission avoidances at the customer's facility, since they represent direct atmospheric releases that were eliminated. Depending on the reporting framework, these may also support disclosure under initiatives such as the Task Force on Climate-related Financial Disclosures (TCFD) or industry-specific ESG benchmarks.

Each Square Robot inspection eliminates one complete emissions event — the equivalent of draining, venting, and refilling an entire tank — that would otherwise be required under the conventional inspection process.

For a 100-ft diameter internal floating-roof tank storing standard gasoline, a single inspection avoids approximately 5–6 tonnes of CO_2e.

INTEGRATING AVOIDED EMISSIONS INTO ESG REPORTING

For sustainability teams managing Scope 1 and Scope 3 emissions inventories, the emissions avoidance generated by Square Robot inspections represents a quantifiable, documented, and methodology-backed reduction in facility-level emissions events.

What This Means for Your Emissions Inventory

Each conventional tank inspection that is replaced by a Square Robot inspection eliminates a discrete, calculable emissions event from your facility's operational footprint. Because the emissions avoided are Scope 1 in nature — direct releases from your storage infrastructure — they can be:

- Reported as avoided emissions in sustainability disclosures with full methodology documentation
- Used to support progress toward absolute Scope 1 reduction targets
- Incorporated into asset-level emissions tracking for storage terminal operations
- Documented as part of an operator's LDAR (Leak Detection and Repair) or emission reduction programs

Model Transparency and Auditability

Square Robot's avoided emissions model was developed and documented by an independent third party, Positive Scenarios Consulting, LLC. The full methodology report and 2026 addendum are available upon request. Key features supporting auditability include:

- Grounded in U.S. EPA AP-42 — the recognized industry standard for stationary source emissions estimation
- Project-specific inputs used wherever available, rather than generic assumptions
- Documented conservatism — the model is designed to underestimate rather than overestimate avoided emissions
- Fuel-specific calculations — each product type has validated parameters based on published specifications and engineering correlations

- Custom RVP inputs available for projects where specific fuel specifications are known

CONCLUSION

The greenhouse gas emissions associated with conventional aboveground storage tank inspection are not widely discussed in industry ESG conversations — but they are real, quantifiable, and avoidable. Every tank inspection that requires pumpout, venting, and refilling is an emissions event. For facilities managing large tank farms with multiple inspection cycles underway at any time, these emissions can represent a meaningful and recurring component of Scope 1 inventory.

Square Robot's in-service inspection technology eliminates these emissions events by design. The tank never empties, the vapor space never forms, and the venting release never happens. The result is an inspection process that delivers superior data quality — high-density PAUT coverage meeting API 653 Annex G requirements — while simultaneously eliminating the environmental impact of the conventional alternative.

With 1,087 tonnes of CO_2e contained to date and a growing portfolio of industries, including power generation, refining, terminal operations, and more, Square Robot offers sustainability teams a tangible, documented, and third-party validated mechanism for reducing facility-level emissions from tank inspection programs.

To receive project-specific emissions avoidance estimates for your facility's tank inspection program, contact Square Robot.

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Emissions data calculated using PSC Avoided Emissions Model v1.2 based on U.S. EPA AP-42 methodology. All figures are conservative estimates.