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Pilot-Scale Catalytic Conversion of Non-Recyclable Plastic Waste into Ultra-Low Sulfur Diesel

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Abstract

The growing accumulation of non-recyclable plastic waste presents a dual challenge of environmental pollution and resource inefficiency. This study presents NeevEnerjet™, a patent-protected catalytic waste-to-fuel technology developed for the conversion of mixed plastic waste into ultra-low sulfur diesel (ULSD)-range fuel, with successful operation demonstrated at both laboratory and pilot scales. The process integrates feed stock preparation, oxygen-free thermal cracking, catalytic upgrading, staged condensation, fraction separation, and post-treatment using a proprietary system and process configuration to produce a diesel-range synthetic fuel suitable for industrial and transportation-relevant applications. A laboratory-scale reactor setup was first used to establish process feasibility and optimize liquid fuel recovery. Following successful bench-scale validation, the process was translated into a 200 liters/day pilot plant, demonstrating engineering scalability under practical operating conditions. The pilot unit includes a thermal conversion reactor, vapor transfer system, multi-stage condensation train, liquid receivers, gas handling, and process control instrumentation. The fuel was clear, light green, and diesel-like. Independent third-party fuel test results were matching diesel properties, thereby placing the fuel within the ultra-low sulfur category and consistent with key EN 590 low-sulfur diesel performance indicators. Diesel fraction recovery of approximately 80 wt% under optimized feed and operating conditions. The results demonstrate that the NeevEnerjet™ catalyst and process technology serve as a viable waste-to-fuel technology with circular-economy relevance, combining plastic diversion with the production of a clean diesel-range liquid hydrocarbon. The work establishes a basis for future scale-up, process intensification, emissions validation, and techno-economic deployment.

Keywords: Plastic Waste-to-Fuel Conversion, Catalytic Pyrolysis, Ultra-Low Sulfur Diesel (ULSD), Waste-to-Energy Technology, Circular Economy and Sustainable Waste Management

INTRODUCTION

Plastic waste has become one of the most persistent environmental pollutants of the modern industrial age. Conventional disposal pathways such as landfill, uncontrolled dumping, and open burning create long-term ecological burdens while also wasting embedded hydrocarbon value. Poly-olefin rich waste plastics, especially polyethylene (PE), polypropylene (PP), high-density polyethylene (HDPE), and low-density polyethylene (LDPE), Cross link polyethylene (XLPE) represent a significant untapped carbon resource due to their high hydrogen and carbon content and relatively low oxygen content compared with biomass-derived feed stocks.

Among the available valorization routes, thermochemical conversion has attracted increasing attention because it can process heterogeneous and contaminated plastic streams that are difficult to recycle mechanically. Pyrolysis and catalytic cracking of waste plastics produce liquid hydrocarbons, non-condensable gases, and carbon residues. However, one of the major limitations of conventional plastic pyrolysis oil is that the crude liquid often lacks direct fuel compliance due to variability in boiling range, instability, olefin content, impurities, and sulfur-associated concerns when mixed feed stocks or downstream contamination are involved.

To address these limitations, the present work focuses on NeevEnerjet™, catalytic conversion technology designed for the production of ultra-low sulfur diesel (ULSD)-range fuel from non-recyclable plastic waste. The technology incorporates a process methodology intended to improve diesel-range hydrocarbon selectivity, product quality, and sulfur control while maintaining practical scalability from laboratory to pilot operation.

Unlike generic plastic pyrolysis studies that focus primarily on crude liquid recovery, the present work is positioned as a **fuel-quality and process-engineering study**, with emphasis on **regulated fuel relevance, pilot-scale validation, and technology readiness**.

The objective of this study is therefore to document the NeevEnerjet™ process, describe the pilot-relevant experimental system, evaluate the produced fuel against key diesel-quality indicators, and establish the technical basis for further commercialization and scientific validation.

A project summary provided for the technology reports that mixed plastic waste is shredded and processed in a catalytic pyrolysis reactor at approximately 350–400°C, followed by condensation, diesel-range separation, and post-treatment to achieve ultra-low sulfur characteristics, with a reported diesel fraction yield of approximately 80 wt% under favorable feed stock conditions. These values, when paired with

verified fuel test data, suggest that the process is not merely a waste destruction system but a fuel with industrial relevance.

The objective of this study is therefore to document the pilot-relevant experimental system, describe the conversion approach, present the observed product characteristics, and evaluate the produced liquid fuel against key diesel quality indicators.



MATERIALS AND METHODS

Feed Stock

The feed stock investigated in this work comprised a broad range of **post-consumer and post-industrial plastic waste**, including **polyethylene (PE)**, **polypropylene (PP)**, **high-density polyethylene (HDPE)**, **low-density polyethylene (LDPE)**, **multi layer mixed plastic fractions**, and **cross-linked polyethylene (XLPE)**. Preliminary conversion trials were conducted across multiple plastic classes to evaluate thermal cracking behavior, condensable hydrocarbon formation, and diesel-range liquid recovery

1. segregated: to remove metal, glass, and obvious inert contaminants,

2. size reduced/shredded: to improve thermal contact and uniform decomposition,

3. optionally pre-dried/preheated to minimize moisture-related disturbance.

The feed stock preparation step is critical because mixed municipal plastic waste often contains labels, dirt, multi layer contamination, and polymer heterogeneity, all of which can influence cracking behavior and downstream fuel quality.



Fig 1 Shredding Machine Fig 2 Shredded XLPE Plastic

Experimental Apparatus

The laboratory-scale experimental setup consisted of a **glass reactor-condensation assembly** mounted on a support frame and heated using a controlled thermal bath system.

- a **reactor vessel** serving as the cracking chamber,
- a vertical distillation column,
- one **water-cooled condensers**,
- intermediate vapor/liquid separation points,

- a **receiver vessel** for condensed liquid collection,
- temperature control instrumentation,
- external cooling and vapor transport tubing.
- Vacuum pump

The apparatus visually resembles a compact catalytic pyrolysis and vapor refining train suitable for proof-of-concept and controlled batch operation. The provided setup image indicates an integrated condensation

method capable of staged vapor cooling and liquid recovery, which is useful for narrowing the product into diesel-range fractions.

This setup is consistent with the process flow described in the project summary, which includes plastic shredding, reactor cracking, distillation, condensation, receiver collection filtration and storage stages.

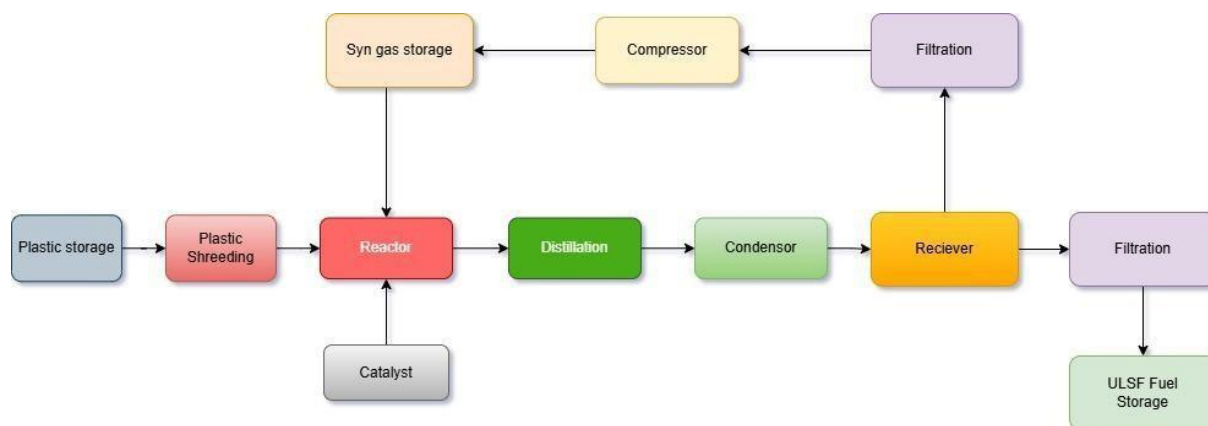


Fig 3 Process Flow Diagram



Fig 4 Experimental setup for catalytic conversion of waste plastic into diesel-range fuel,

The waste plastic feed was introduced into the reactor under **oxygen-limited / oxygen-free conditions** to prevent combustion and promote thermochemical cracking. The system was gradually heated to the desired cracking temperature and processed using the **catalyst and process technology**, which is protected through intellectual property filings and proprietary know-how., the process temperature range for the cracking zone was approximately **350–400°C** in the operational summary, while the broader concept includes higher cracking ranges depending on polymer type and catalytic severity.

Because the catalyst composition and certain process conditions constitute **protected intellectual property**, only non-confidential operational details are disclosed in the present paper. The process employs a **proprietary catalytic environment** to promote polymer-chain scission, hydrocarbon vapor generation, and diesel-range selectivity, followed by controlled vapor transfer, staged condensation, liquid collection, and post-treatment..

During heating:

- polymer chains underwent **catalytic cracking**,
- volatile hydrocarbons exited the reactor as **vapors**,
- vapors passed through the **condensation train**,
- condensed liquids were collected as hydrocarbon product,

Catalytic Conversion Procedure

- non-condensable gas was separated for handling or auxiliary use,
- heavier or undesired fractions were minimized through staged thermal and condensation control.

This framework constitutes the **NeevEnerjet™ catalytic process pathway** for producing a refined diesel-range hydrocarbon from otherwise low-value non-recyclable plastic waste.

Role of Catalyst in Achieving Ulsd Grade Fuel

The attainment of ULSD fuel in the present work, despite the absence of hydro treating, highlights the effectiveness of the catalytic upgrading pathway employed. Since sulfur in waste plastic feed stocks is generally present at much lower levels than in crude-oil-derived refinery streams, the sulfur burden of the pyrolysis oil is already comparatively limited and is primarily associated with contamination, additives, and non polyolefin fractions. The catalyst appears to facilitate selective vapor-phase upgrading by enhancing cracking efficiency, reducing the transfer of sulfur-associated heavy fractions, and improving the separation of clean diesel-range hydrocarbons from unstable hetero atom-rich components. Furthermore, controlled condensation and fractionation enable preferential recovery of the middle-distillate fraction while minimizing contamination from heavier residual species. Consequently, a low-sulfur upgraded fuel was obtained without hydrogen consumption, conventional refinery desulfurization infrastructure, demonstrating the potential of catalytic plastic-to-fuel conversion as a simpler and economically attractive alternative route for producing diesel-range fuel.

Fuel Upgrading and Product Recovery

The liquid product obtained after primary condensation was subjected to **diesel-range fraction selection and polishing**. According to the supplied process summary, the system includes **post-treatment** intended to achieve ultra-low sulfur and low-smoke combustion characteristics.

The final product was visually observed as a **clear to light green liquid hydrocarbon**, with photographs showing relatively clean, low-haze fuel samples. This visual characteristic is important because many untreated plastic pyrolysis oils are dark, unstable, or resinous; a lighter and

clearer fraction often indicates improved product quality and narrower boiling-range selection.



Fig 5 Fuel sample



Fig 6 Fuel Sample

Fuel Testing and Characterization

We submitted the fuel for laboratory testing against diesel-relevant properties. The independent test report supplied with the present material indicates analysis under diesel specification logic and provides the following measured values for the sample identified as **plastic-derived diesel**:

- **Appearance:** Clear, bright and free from sediments, suspended matter and undissolved water
- **Density at 15°C:** 831.1 kg/m³
- **Kinematic viscosity at 40°C:** 2.438 cSt
- **Distillation recovery (95% v/v):** 349.8°C
- **Flash point (Abel):** 45.5°C
- **Cetane index:** 52.1
- **Total sulfur:** 6.6 mg/kg
- **Copper strip corrosion (3 h at 50°C):** 1a
- **Pour point (winter):** -12°C

These properties were evaluated against diesel-relevant benchmark ranges and are discussed below.

TEST REQUIRED:		HSD BATCH FORMATION TEST(2017)		Inspection Lot / Report No.:	/90005284200
Industry Standard:		IS 1460:2025		Sample Identification No.:	LDI/2025-26/L009027
Customer:		"neev"bioreports"		Lot Batch:	DUTYPAIDFG
Batch Number:		NA		Customer Tank No.:	1
Sample Drawn By:		SWAPNIL		Stock Represented:	1,000 KL
Type of Sample:		COMPOSITE		Sample Drawn Date:	15.01.2026
Reason for Testing:		PLASTIC DERIVED DIESEL		Sample Receipt Date:	15.01.2026
Note:				Seal No. I/O	/
				Lot Release Date	31.01.2026

SL NO.	CHARACTERISTIC	TEST METHOD	SPECIFICATION LIMIT & UNIT	TEST RESULTS
	Operation : 00000001	Batch Formation Test		
1	Appearance	VISUAL APPEARANCE	CLEAR, BRIGHT AND FREE FROM SEDIMENTS, SUSPENDED MATTER AND UNDISSOLVED WATER AT NORMAL AMBIENT FUEL TEMPERATURE	CLEAR, BRIGHT AND FREE FROM SEDIMENTS, SUSPENDED MATTER AND UNDISSOLVED WATER AT NORMAL AMBIENT FUEL TEMPERATURE
2	Density at 15°C	IS 1448 P-16	810.0 .. 845.0 kg/m ³	831.1
3	Kinematic Viscosity at 40°C	D 7042	2,000 .. 4,500 cSt	2,438
4	Dist - 95%(v/v) Recovery	IS 1448 P-18	Max. 360.0 °C	349.8
5	Flash Point (Abel)	IS 1448 P-20	Min. 35.0 °C	45.5
6	Cetane Index	ASTM D4737	Min. 46.0	52.1
7	Total Sulphur	ASTM D5453	Max. 10.0 mg/kg	6.6
8	CopperStrip Corrosion for 3h at 50°C Max	IS 1448 P-15	Not Worse than No.1	1a
9	Pour Point (Winter)	IS 1448 P-10 SEC 2	Max. 3.°C	-12

Fig 7 ULSD Test report

Pilot Plant Development and Scale-up Validation

Following successful laboratory-scale validation, the **NeevEnerjet™ process technology** was translated into a **pilot-scale conversion system with a nominal production capacity of 200 liters/day** of liquid hydrocarbon product under designed operating conditions. The objective of this scale-up was to evaluate whether the catalytic plastic-to-fuel process could be practically implemented beyond bench-scale glassware and whether the vapor generation, condensation, collection, and process-control logic remained effective under higher-throughput operation.

The pilot unit, as shown in the experimental photographs, consists of a **thermochemical conversion reactor**, feed introduction section, vertical vapor handling columns, condensation train, liquid collection receivers, auxiliary gas handling line, and electrical process-control panel. The reactor is mounted on a structural

frame and integrated with downstream separation and condensation hardware to enable batch fuel recovery. Compared with the laboratory glass setup, the pilot system provides a more industrially relevant configuration for validating heat transfer, vapor residence behavior, condensation efficiency, and product handling.

Operating the 200 L/day NeevEnerjet™ pilot plant marks a key transition from lab proof-of-concept to engineering demonstration—a milestone rarely achieved in waste-to-fuel research. The pilot plant confirms that the developed process architecture is capable of being translated into a larger scale

The pilot unit establishes a practical foundation for future studies involving:

- feed handling,
- energy integration,
- gas recycling,
- catalyst life evaluation,
- emissions monitoring,
- process automation,



Fig 8 Pilot scale Plant

Non Condensable Gas Recovery and Utilization

The **non-condensable gas fraction** generated during the catalytic conversion of plastic waste was not vented or discarded. Instead, the recovered gas stream was subjected to **basic filtration and particulate removal**, followed by **compression and temporary storage** for controlled reuse within the process system. The stored gas was subsequently utilized as a **supplementary burner fuel** for thermal support applications, thereby improving overall process energy efficiency and reducing dependence on external fuel input.

This internal gas recovery and reuse strategy enhances the practical engineering relevance of the **NeevEnerjet™ process**, as it enables partial valorization of the gaseous by-product stream while supporting a more integrated waste-to-fuel operating model.

RESULTS AND DISCUSSION

Product Appearance and Physical Observations

The produced fuel samples were visually clear and light green and appeared substantially cleaner than crude, untreated pyrolysis liquids typically reported in early-stage waste plastic fuel experiments. The provided bottle images show relatively transparent liquid fractions with low suspended contamination, indicating effective condensation and at least partial downstream purification.

This is an important practical observation because fuel appearance, while not sufficient alone for specification compliance, often correlates with:

- reduced heavy tar carryover,
- improved fraction control,
- lower particulate contamination,
- better handling stability.

The presence of a distinct diesel-like liquid phase also supports the effectiveness of the condensation and separation strategy employed in the experimental system.

Material Balance and Product Distribution

A representative material balance for the **catalytic conversion process** indicated that **1 kg of non-recyclable plastic feed stock** produced approximately **0.80 kg diesel-range liquid hydrocarbon**, **0.15 kg non-condensable hydrocarbon-rich process gas**, and **0.05 kg carbonaceous**

residue / char under optimized operating conditions. This corresponds to an overall liquid recovery of **80 wt%**, with the diesel-range fraction representing the dominant product stream.

The observed product distribution is consistent with thermochemical cracking behavior expected from **polyolefin-rich plastic feed stocks**, where long-chain polymer molecules undergo catalytic chain scission to generate a broad hydrocarbon spectrum spanning light condensable, diesel-range liquids, and gaseous hydrocarbons. The relatively low solid residue fraction suggests effective thermal conversion, while the non-condensable gas fraction

may offer potential for internal heat recovery or auxiliary process energy integration in future scaled systems.

$$100\% \text{ Plastic Feed} = 80\% \text{ ULSD} + 15\% \text{ Non-Condensable gas} + 5\% \text{ Carbon residue}$$

Fuel Property Evaluation

Density

The measured density of **831.1 kg/m³ at 15°C** lies comfortably within the expected range for automotive diesel fuels. A density in this range is favorable for injection behavior, volumetric energy delivery, and compatibility with conventional diesel engine systems.

Kinematic Viscosity

The measured kinematic viscosity of **2.438 cSt at 40°C** indicates a fluidity appropriate for fuel injection systems and automation. Excessively low viscosity can impair lubrication, whereas excessively high viscosity can compromise spray quality. The observed value falls in a technically acceptable diesel-like range and suggests the product is significantly more refined than raw plastic pyrolysis condensate.

Cetane Index

The measured cetane index of **52.1** is especially notable. Cetane is a key indicator of ignition quality in compression ignition engines. A cetane index above 51 suggests favorable ignition characteristics, reduced ignition delay, and better cold-start and combustion behavior compared with lower-quality cracked oils.

Sulfur Content

The most commercially and scientifically important result is the **total sulfur content of 6.6 ppm**, which is below the **10 ppm** threshold associated with **ultra-low sulfur diesel** classes.

A sulfur level below 10 ppm is significant because:

- it reduces sulfur oxide (SO_x) emissions,
- improves compatibility with modern emission-control systems,
- supports cleaner combustion,
- enhances regulatory relevance for advanced diesel applications.

Distillation Recovery

The **95% distillation recovery at 349.8°C** indicates the recovered product is strongly centered in the diesel boiling

range rather than being dominated by light fraction or excessively heavy waxy fractions. This supports the claim that the process is not merely producing generic pyrolysis oil, but a fuel fraction with meaningful diesel-range character.

Flash Point

The measured flash point of **45.5°C** is above the minimum requirement cited in the test report and indicates acceptable handling safety compared with very volatile light hydrocarbon mixtures. Although flash point can still be further optimized depending on target end use and standard, this result supports the practical viability of the product.

Corrosion and Low-temperature Behavior

The **copper strip corrosion rating of 1a** indicates low corrosive aggressiveness, while the **pour point of -12°C** suggests reasonable low-temperature operability for many climates and industrial applications.

Table 1. Fuel properties of plastic-derived ULSD

Parameter	Measured Value	Diesel Relevance
Appearance	Clear and bright	Favorable
Density @ 15°C	831.1 kg/m ³	Within diesel range
Kinematic viscosity @ 40°C	2.438 cSt	Suitable
95% Distillation recovery	349.8°C	Diesel-range fraction
Flash point	45.5°C	Acceptable
Cetane index	52.1	Strong ignition quality
Total sulfur	6.6 ppm	ULSD-level
Copper strip corrosion	1a	Low corrosive

Carbon Residue Valorization Potential

In addition to the liquid and gaseous product streams, the **NeevEnerjet™ process** generated a **solid carbon residue** accounting for approximately **5 wt%** of the initial plastic feed under representative operating conditions. Rather than being treated solely as a low-value by-product, this recovered carbon fraction is being investigated for **advanced pathways**.

Preliminary internal development efforts are currently focused on the **conversion of the recovered carbon residue into graphene**, subject to ongoing process optimization and materials characterization. It represents a promising opportunity to further enhance the circular-economy value of

the process by converting a secondary residue stream into a potentially high-value carbon material.

This aspect is particularly relevant from a waste-to-value perspective, as it indicates that the **NeevEnerjet™ technology** ultimately function not only as a fuel-generation technology but also as a **multi-product resource recovery system** capable of producing liquid fuel, reusable process gas, and advanced carbon precursors from non-recyclable plastic waste.

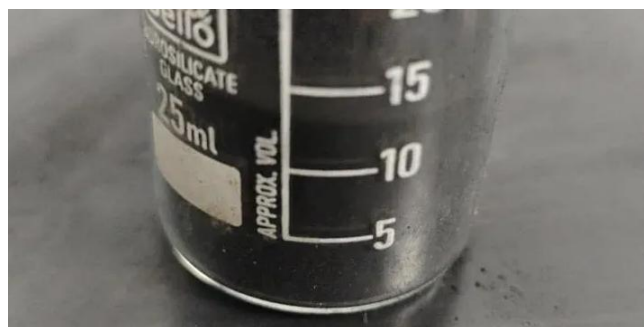


Fig 9 Carbon Residue

Comparison with Conventional Plastic Pyrolysis Oil

A key publication angle is that your product should be framed not as “**plastic pyrolysis oil**” but as “**Diesel-range synthetic fuel derived from plastic waste.**”

Typical plastic pyrolysis oil often suffers from:

- broader boiling distribution,
- unstable composition,
- sulfur
- poor flash characteristics,
- unsuitability for direct diesel substitution.

Table 2 : Comparative Fuel Properties of SGS-Tested ULSD, IOCL-Tested ULSD, and Raw Plastic Pyrolysis Oil

Property	SGS-Tested ULSD	Independent IOCL-Tested ULSD	Raw Plastic Pyrolysis Oil (PPO)	Unit
Appearance	Clear & Bright	Clear, Bright, Free from impurities	Dark brown / black	—
Density @ 15°C	810	831.1	850 – 950	kg/m ³
Kinematic Viscosity @ 40°C	2.032	2.438	5 – 15	cSt
Flash Point	40	45.5	30 – 50	°C
Pour Point	-3	-12	5 to 20	°C
Sulfur Content	8	6.6	500 – 1000	ppm
Cetane Index	53.6	52.1	25 – 40	—
Carbon Residue	0.30	—	0.5 – 2.0	%
Ash Content	0.001	—	0.05 – 0.2	%
Water & Sediment	0.02	—	0.1 – 1.0	%
Acid Number	0.04	—	1 – 10	mg KOH/g
Copper Strip Corrosion	1a	1a	Variable	Rating
Distillation Range	124 – 373	Up to 349.8 (95%)	100 – 450	°C
Recovery	98	95	Lower	%

Yield and Process Efficiency

The **final diesel fraction yield of approximately 80 wt%** under favorable operating conditions. Trials also suggests that XLPE / HDPE - rich feed stocks can provide the highest ULSD range output among tested polymers.

If substantiated further through replicated runs, this yield level is commercially meaningful because it indicates high liquid recovery from low-value plastic waste. In industrial practice, the economics of waste-to-fuel systems depend strongly on:

- liquid yield,
- catalyst life,
- energy integration,
- residue handling,
- fuel polishing cost,
- plant throughput.

Environmental and Circular-economy Relevance

This process has importance beyond fuel production. It addresses three interconnected problems:

1. Plastic waste management

Non-recyclable plastic waste that would otherwise be landfill, burned, or leaked into the environment is redirected into productive use.

2. Fuel substitution

The produced liquid hydrocarbon has potential as a substitute or blend component for fossil-derived diesel in suitable applications.

3. Localized energy resilience

Decentralized or modular conversion systems can reduce transport burden associated with both waste disposal and fuel supply.

In circular-economy terms, the process converts a **negative-value waste stream** into a **positive-value liquid fuel**, while also producing gas and solid by-products that may be recoverable or usable depending on process integration.

Pilot-scale Engineering Significance

In real waste-management environments, feed stocks are rarely composed of pure single-polymer streams. The observed broad feed stock tolerance therefore strengthens the industrial applicability of the technology, particularly for decentralized or modular waste-to-fuel systems.

A major contribution of the present work is the successful development of a **200 liters/day pilot plant**, which substantially improves the practical significance of the study. In many published plastic pyrolysis investigations, promising liquid yields are reported only at flask or micro reactor scale,

leaving uncertainty regarding thermal uniformity, vapor transport, condensation behavior, and real process scalability. By contrast, the present system demonstrates that the developed catalytic plastic-to-fuel pathway can be implemented in a physically integrated pilot-scale unit.

The pilot plant provides several technical advantages over purely laboratory systems:

1. Improved process realism

Larger reactor volume and industrial-style vapor routing provide conditions more representative of future commercial deployment.

2. Better evaluation of condensation and fractionation

Multi-stage collection improves assessment of diesel-range liquid recovery and helps minimize uncontrolled broad-spectrum condensate collection.

3. Operational relevance

The pilot unit allows validation of control logic, thermal response, liquid handling, and process stability under more practical conditions.

4. Commercial readiness signal

The existence of a working pilot plant strengthens the case for industrial application, licensing, investment, and regulatory engagement.

The successful operation of the pilot plant therefore represents not only a scale increase but also a meaningful **technology readiness advancement** for the conversion of plastic waste into ultra-low sulfur diesel-range fuel.

CONCLUSION

This study demonstrates the technical feasibility of converting non-recyclable plastic waste into a diesel-range hydrocarbon product exhibiting **ultra-low sulfur characteristics** and favorable combustion-related properties, through the **NeevEnerjet™ patented catalyst and process technology**. Using a catalytic thermochemical conversion approach coupled with staged condensation and fuel upgrading, a clear, low-sulfur liquid product was obtained from mixed waste plastics.

The successful design and operation of a **pilot plant** further strengthen the practical and commercial significance of the work, demonstrating that the catalytic process can move beyond laboratory proof-of-concept into engineering validation scale. The combination of **catalyst technology**, **broad plastic feed stock compatibility**, and **verified low-sulfur fuel quality** establishes a promising foundation for

future industrial scale-up, engine validation, emissions benchmarking, and techno-economic deployment.

Overall, the present work provides a strong applied foundation for waste plastic to ULSD conversion as a practical circular-energy technology.

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CONFLICT OF INTEREST STATEMENT

The authors declare that the work relates to a proprietary and patented technology for conversion of waste plastic into ultra-low sulfur diesel-range fuel.

REFERENCES

- [1]. S. M. Al-Salem, P. Lettieri, and J. Baeyens, "Recycling and recovery routes of plastic solid waste (PSW): A review." <https://doi.org/10.1016/j.wasman.2009.06.004>
- [2]. G. Lopez, M. Artetxe, M. Amutio, J. Bilbao, and M. Olazar, "Thermochemical routes for the valorization of waste polyolefinic plastics to produce fuels and chemicals: A review." <https://doi.org/10.1016/j.rser.2017.01.142>
- [3]. S. M. Al-Salem, A. Antelava, A. Constantinou, G. Manos, and A. Dutta, "A review on thermal and catalytic pyrolysis of plastic solid waste (PSW)." <https://doi.org/10.1016/j.jenvman.2017.03.084>
- [4]. "A review on the pyrolytic conversion of plastic waste into fuels and chemicals." *Journal of Analytical and Applied Pyrolysis* (2024). <https://doi.org/10.1016/j.jaap.2024.106479>
- [5]. "Pyrolysis of waste plastics into fuels and chemicals: A review." *Renewable and Sustainable Energy Reviews* (2023). <https://doi.org/10.1016/j.rser.2023.113799>
- [6]. "Plastic waste as pyrolysis feedstock for plastic oil production: A review." *Science of the Total Environment* (2023). <https://doi.org/10.1016/j.scitotenv.2023.162719>
- [7]. "Recent advances in liquid fuel production from plastic waste via pyrolysis: Emphasis on polyolefins and polystyrene." *Environmental Research* (2024). <https://doi.org/10.1016/j.envres.2024.118154>
- [8]. I. Barbarias, M. Artetxe, G. Lopez, A. Arregi, L. Santamaria, J. Bilbao, and M. Olazar, "Catalyst

- Performance in the HDPE Pyrolysis-Reforming under Reaction-Regeneration Cycles.” Catalysts (2019). <https://doi.org/10.3390/catal9050414>
- [9]. “A review on catalytic pyrolysis of municipal plastic waste.” WIREs Energy and Environment (2023). <https://doi.org/10.1002/wene.495>
- [10]. ASTMInternational, ASTM D5453 — Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Fuels, and Engine Oil by Ultraviolet Fluorescence. <https://store.astm.org/standards/d5453>
- [11]. British Standards Institution, BS EN 590 — Automotive Fuels: Diesel—Requirements and Test Methods. <https://knowledge.bsigroup.com/products/automotive-fuels-diesel-requirements-and-test-methods-7>