

# Method for Converting Waste Plastic to Hydrocarbon Fuel Materials

Dr. Moinuddin Sarker

Natural State Research, Inc.  
37 Brown House Rd., Stamford, CT 06902  
msarker@naturalstateresearch.com

## ABSTRACT

The increased demand and high price for energy sources are driving efforts to convert organic compounds into useful hydrocarbon fuels. Although much of this work has focused on biomass, there are strong benefits to deriving fuels from waste plastic material. Natural State Research (NSR) has invented a simple and economically viable process to decompose the hydrocarbon polymers of waste plastic into the shorter chain hydrocarbons of liquid fuel (patent pending). The method and principal of the production / process will be discussed. Initial tests with several widely used polymers indicate a high potential for commercialization.

**Keywords:** waste plastic, hydrocarbon fuels, catalytic cracking, gas chromatography, dynamic scanning calorimetry

## 1 INTRODUCTION

Economic, political and environmental pressures provide the motivation to reduce the use of conventional transportation fuels. In the past year, gasoline and diesel have been subject to large price swings that strongly affect regional economics and transportation planning and budgeting. Although fuel prices are currently very low, it can be assumed that prices will return to higher levels in the future as economic conditions improve and demand increases relative to supply. Even with the current low prices for fuel, New York State residents and businesses pay the highest gasoline and diesel prices in the continental United States (only Alaska and Hawaii have higher prices). Transportation fuels are predominantly derived from imported oil, which creates an economic and political dependence on foreign countries.

In urban areas throughout New York, vehicle emissions are the largest single source of air pollution and greenhouse gases. Emissions from gasoline cars include unburned hydrocarbons, which are responsible for ground-level ozone and smog; nitrogen oxides (NO<sub>x</sub>), which contribute to ozone and acid rain; carbon monoxide (CO), a toxic byproduct of incomplete combustion and a health hazard; sulfur dioxide (SO<sub>2</sub>), which contributes to acid rain; and carbon dioxide

(CO<sub>2</sub>), a greenhouse gas that contributes to global warming. The exhaust from gasoline vehicles or from evaporative emissions include many other harmful compounds, including benzene, toluene, xylenes, styrene, 1,3-butadiene, aldehydes and ketones, phenols, halogenated hydrocarbons, and trace metals. The EPA has recently reduced the allowable sulfur content in gasoline and diesel fuel. However, the reduction of sulfur adds expense to the fuel manufacturing process.

The American Lung Association rates portions of New York State as having poor air quality. Out of 28 counties with monitoring systems, seven received a grade of D or F for high ozone days (2008). Eight counties received a grade of C, and 13 counties received a grade of B or A. Two counties received annual failing grades for particle pollution in 2008.

Alternative fuels developed from a reliable domestic source have the potential to overcome many economic and environmental problems, by providing a steady, low cost source of fuel, by providing local employment in energy production, and by providing fuel types that are cleaner and produce fewer harmful emissions. A great deal of research and development in alternative fuels has focused on biomass, for example, creating cellulosic ethanol from non-edible biomass sources. However, biomass energy requires large amounts of arable land to be devoted to the cultivation of plant sources.

There are also strong benefits to deriving fuels from waste plastic material. Waste plastic is abundant and its disposal creates large problems for the environment. Plastic does not break down in landfills, it is not easily recycled, and it degrades in quality during the recycling process. However, chemical processes such as pyrolysis and depolymerization can be used to safely convert plastics into hydrocarbon fuels that can be used for transportation [1-3]. The United States produces 30 million tons of plastic waste per year, and since one ton of plastic can be converted into 420 gallons of fuel, there is the potential to create 12.6 billion gallons of fuel nationwide annually from waste plastic. This could replace up to 9% of U.S. gasoline consumption.

Companies worldwide are making inroads in the waste plastic-to-fuel arena. Australian company OzmoTech (<http://www.ozmotech.com.au/>) converts waste plastic to diesel fuel through a process that includes liquefaction, pyrolysis, catalytic breakdown of high molecular weight vapors, and controlled distillation. The resulting fuel is compliant with European regulatory standards and can run

any diesel engine without modification. A plant in India, Unique Plastic Waste Management & Research Co Pvt Ltd, has already demonstrated commercial success and electrical self-sufficiency by converting waste plastic into fuel, using a low-temperature melting process with degasification, and depolymerization with a proprietary catalyst. The produced liquid hydrocarbon fuel is a sulfur-free industrial crude oil, which can be used in furnaces or further processed to obtain a finer grade. In the United States, Polymer Energy LLC (<http://www.polymerenergy.com/>), located in Minnesota, processes polyethylene (PE) and polypropylene (PP) plastic waste into a high grade crude oil using catalytic pyrolysis. Global Resource Corporation in New Jersey (<http://www.globalresourcecorp.com/>) uses microwaves to release hydrocarbon materials from any waste product and to convert them to useful oil and gas.

Natural State Research, Inc., uses a patent-pending process to convert waste plastic to a liquid hydrocarbon fuel, and has successfully demonstrated the technology on a laboratory scale. The advantages of NSR's technique are its simplicity, which would allow municipalities to construct local fuel production plants; its ability to handle many plastic types; and its ability to produce a variety of fuel types for different transportation needs, e.g., for gasoline, diesel, or aviation fuel engines.

## 2 PROCESS DESCRIPTION

The process involves heating the plastic to form a liquid slurry (thermal liquification in the range 370°-420°C), partial cooling of the slurry, distilling the slurry in the presence of a cracking catalyst, condensing the distillate to recover the liquid hydrocarbon fuel, and routing the remaining slurry residue back into fresh slurry to undergo another catalyzed distillation/condensation process. No additional chemicals are used in the thermal liquification phase, and a commercially available cracking catalyst is used in the distillation and condensation phases. The catalyst is available for reuse when the slurry residue is routed back for inclusion in a fresh batch of slurry. Chlorine from vinyl/polyvinyl chloride plastics is removed and collected via a water scrubbing process. The fuel is filtered using a commercial fuel filter that operates using coalescence and centrifugal force.

Small-scale conversion tests have been performed with the simplified process shown in figure 1, on various waste plastic types: polyethylene terephthalate (PET, code 1), high density polyethylene (HDPE, code 2), vinyl/polyvinyl chloride (PVC, code 3), low density polyethylene (LDPE, code 4), polypropylene (PP, code 5), polystyrene (PS, code 6), and other types (code 7). These plastic types were investigated singly and in

combination with other plastic types, with input weights ranging from 300 gm to 3 kg. The plastics are collected, optionally sorted, cleaned of contaminants, and cut or divided into small pieces prior to the thermal liquification process. NSR's process does not exclude the use of random mixtures of plastic types. In the laboratory scale tests, the weight of a single batch of input plastic for the fuel production process ranges from 300 grams to 3 kilograms.

Preliminary tests on the produced NSR fuel have shown that it is a mixture of various hydrocarbons having a range of carbon chain lengths, from C3 to C27. The sample fuel's density is 0.776 gm/ml; this value is slightly higher than the density for gasoline (0.711 – 0.770 gm/ml) and lower than the density for kerosene (0.82 gm/ml). The fuel is highly flammable and volatile, and has been shown to successfully run a gas-powered generator, a gas-powered lawn mower, and an automobile in preliminary tests.

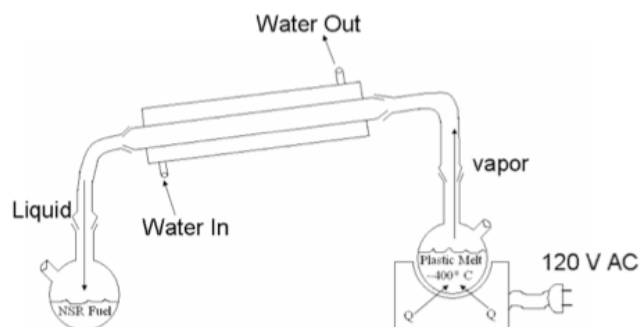
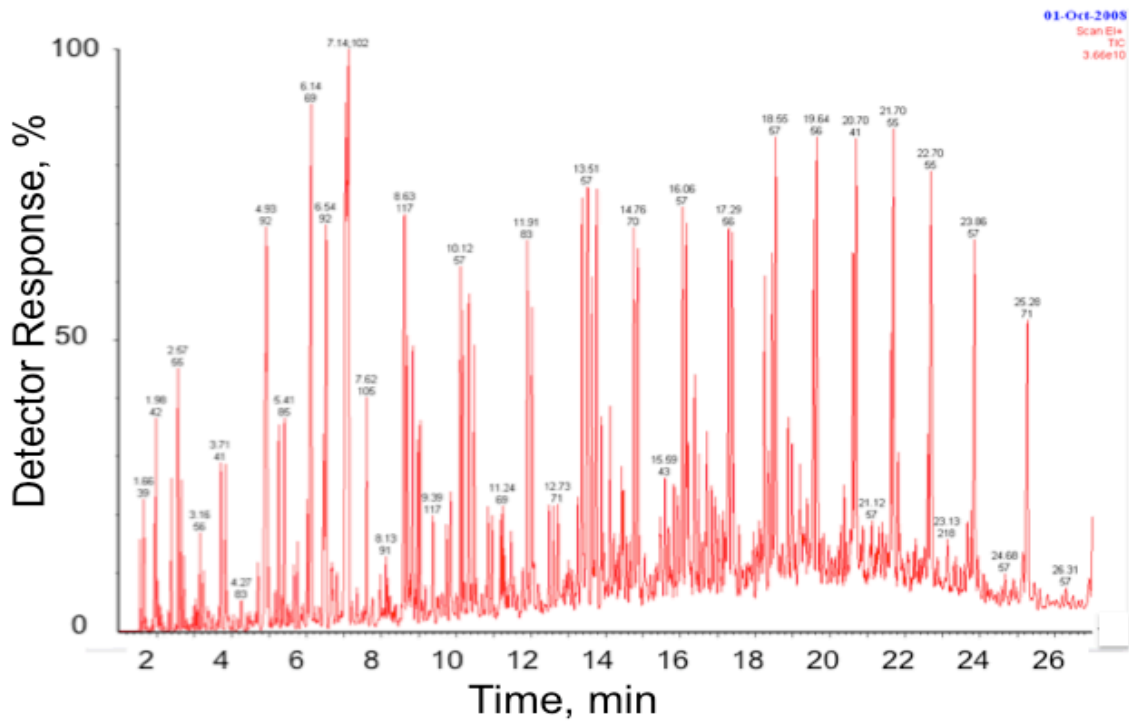


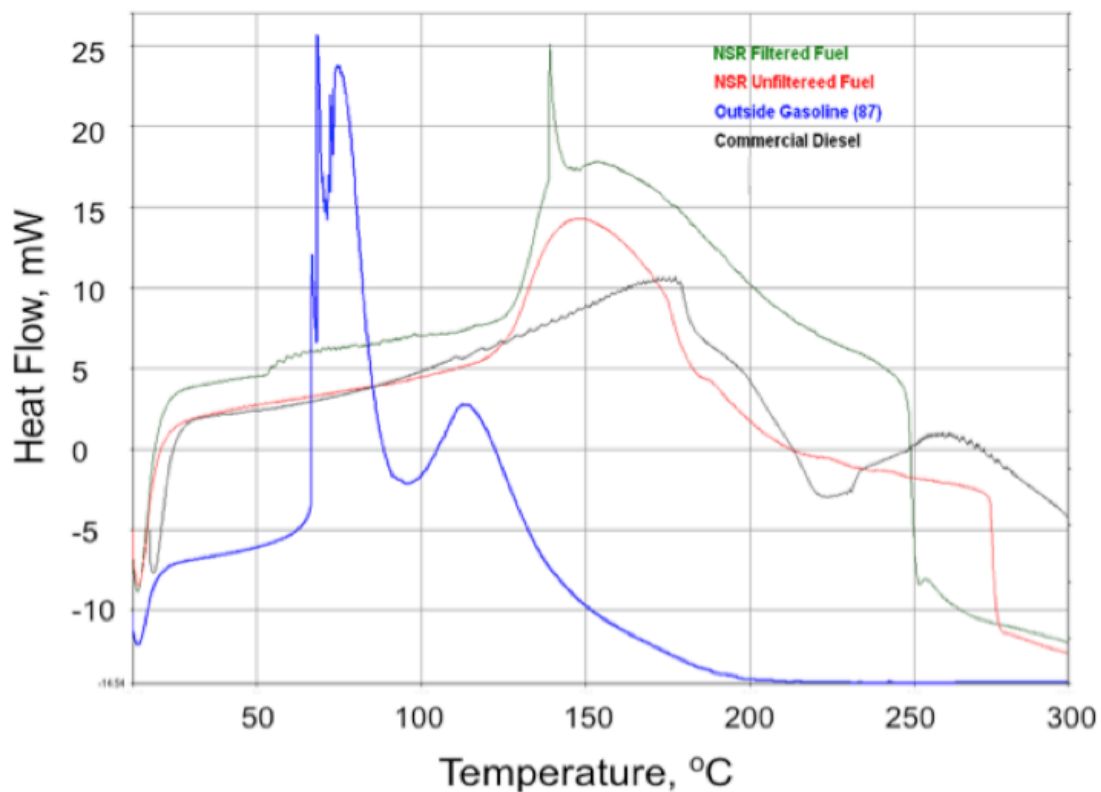
Figure 1. Waste plastics to fuel process.

## 3 FUEL CHARACTERIZATION

Tests have been performed to investigate the composition of the produced fuel. The NSR fuel contains eight additional hydrocarbon groups (C3-C27) compared with commercial gasoline with an octane rating of 87 and containing 10% ethanol (C4-C20). Gas chromatography (GC) tests, Figure 1, show an almost equal peak intensity distribution throughout the chromatogram, with retention times ranging from 2 min to 27 min. This indicates that the NSR fuel has almost equally distributed propane to tetracosane (C3 to C24) compounds. In comparison, a gasoline chromatogram shows an equal peak intensity distribution up to the retention time of 14 min. For longer retention times, the peak intensities are decreased. Thus, gasoline has a higher intensity of hydrocarbon compounds (C4 to C12) at the lower retention times, and fewer hydrocarbon compounds (C13 to C20) in the retention time range of 14 to 27 min. It is also observed that NSR fuel has a higher intensity of straight chain hydrocarbon compounds compared with gasoline.



**Figure 2.** Gas Chromatogram of raw NSR fuel produced from polyethylene showing detector response vs retention time. Mass spectra of the individual peaks indicate the material is nearly all straight chain hydrocarbons.



**Figure 3.** DSC curves of several fuels illustrating different boiling curves.

A comparative analysis using a differential scanning calorimeter, Figure 3, shows that NSR fuel has a much higher boiling point than gasoline (120.99°C vs. 68.19°C, respectively). These values indicate that NSR fuel has more long chain hydrocarbon compounds than gasoline, and these chains can be shortened during the double condensation process. The NSR fuel contains a higher percentage of highly volatile hydrocarbon compounds. Experiments with 2 ml samples showed that NSR fuel required 4.48 minutes to burn, while gasoline required 1.72 minutes to burn. This slower burning is consistent with NSR fuel containing higher molecular weight compounds than light fuels such as gasoline. Gasoline, however, has higher concentrations of benzene, toluene, styrene, xylene, and naphthalene compounds compared with the NSR fuel. Furthermore, unlike gasoline, NSR fuel contains no sulfur so its emissions are free of harmful sulfur dioxide.

#### 4. SUMMARY

A simple catalytic process for depolymerizing waste plastic to synthetic crude oil has been developed. Characterization studies by GC and GC-MS indicate the depolymerization product is essentially all straight chain hydrocarbons when linear thermoplastic polymers are used as the feed. Both GC and DSC studies indicate the product includes hydrocarbons ranging from C<sub>3</sub> to C<sub>27</sub>, a range that includes gasoline and diesel fuel. Additional characterization is underway to measure the double bond frequency in the material, the aromatic content of product produced from polystyrene and other plastics, as well as fractionated portions of the product.

#### REFERENCES

- [1] J. Nishino, M. Itoh, T. Ishinomori, N. Kubota and Y. Uemichi, Development of a catalytic cracking process for converting waste plastics to petrochemicals, *J. Mat. Cycles Waste Manage.*, **5**(2), 89-93, 2003.
- [2] A. Marcilla, A. Gómez-Siurana and F. Valdés, Catalytic cracking of low-density polyethylene over H-Beta and HZSM-5 zeolites: Influence of the external surface. Kinetic model, *Polym. Degrad. and Stability*, **92**(2), 197-204, 2007.
- [3] G. Manos, "Catalytic Degradation of Plastic Waste to Fuel Over Microporous Materials" Chapter 7 in *Recycling of Waste Plastics: Pyrolysis and Related Feedstock Recycling Techniques*, (Eds: J. Scheirs, W. Kaminsky), J. Wiley, 193-208, 2006.