

**BLENDED FUEL COMPOSITIONS INCLUDING PLASTIC PYROLYSIS OIL AND
METHODS OF MAKING THEREOF**

FIELD

[0001] The present disclosure relates to blended fuel compositions that include plastic pyrolysis oil including the total liquid product or a fraction thereof as a blending fuel and methods of making thereof.

BACKGROUND

[0002] For high quality recycling that leads to plastic products that can again be mechanically recycled, plastic waste must be separated by polymer type and thoroughly cleaned. Typically, plastic waste is not properly segregated and is, consequently, downgraded into inferior products that then cannot be mechanically recycled further and often will later be incinerated (Waste-to-Energy) or discarded into a landfill or the environment.

[0003] An alternative to discarding plastic waste into landfills or mechanically recycling plastic waste is pyrolysis. Pyrolysis of plastic waste typically involves heating the plastic waste and entrained organic material in a low oxygen environment. Depending on the conditions of pyrolysis, a plastic pyrolysis oil having a broad boiling range can be obtained. Said plastic pyrolysis oil, typically with additional purification processing, can be used as at least a portion of a blendstock for upgrading to plastic polymer. This pyrolysis processing provides a plastic blendstock for a more circular plastic economy.

[0004] While there are many applications for plastic pyrolysis oil, applications that require minimal or no further processing after pyrolysis would be the most economically beneficial while still providing a path to a more circular plastic economy.

SUMMARY

[0005] The present disclosure relates to blended fuel compositions that include plastic pyrolysis oil including the total liquid product or a fraction thereof as a blending fuel.

[0006] A first nonlimiting example method of making a blended fuel composition of the present disclosure comprises: blending a plastic pyrolysis oil with a blendstock fuel to produce a blended fuel composition, wherein the blended fuel composition comprises about 1 vol% to about 20 vol% of the plastic pyrolysis oil and about 80 vol% to about 99 vol% of the blendstock fuel, and wherein a combination of the plastic pyrolysis oil and the blendstock fuel is selected from the group consisting of: a naphtha fraction of the plastic pyrolysis total liquid product and gasoline; a distillate fraction of the plastic pyrolysis total liquid product and diesel; the distillate fraction of the plastic pyrolysis total liquid product and a marine fuel; a heavy pyrolysis fuel fraction of the

plastic pyrolysis total liquid product and the marine fuel; and the plastic pyrolysis total liquid product and the marine fuel.

[0007] A nonlimiting example of a blended fuel composition of the present disclosure comprises: about 1 vol% to about 20 vol% of a plastic pyrolysis oil and about 80 vol% to about 99 vol% of the blendstock fuel, and wherein a combination of the plastic pyrolysis oil and the blendstock fuel is selected from the group consisting of: a naphtha fraction of the plastic pyrolysis total liquid product and gasoline; a distillate fraction of the plastic pyrolysis total liquid product and diesel; the distillate fraction of the plastic pyrolysis total liquid product and a marine fuel; a heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel; and the plastic pyrolysis total liquid product and the marine fuel.

DETAILED DESCRIPTION

[0008] The present disclosure relates to blended fuel compositions that include plastic pyrolysis oil including the total liquid product or a fraction thereof as a blending fuel. Advantageously, the plastic pyrolysis oil described herein has a low oxygen content, a low sulfur content, and a high hydrocarbon content. Such a composition allows for the plastic pyrolysis oil (total liquid product or fractions thereof) to be blended with blendstock fuels (e.g., marine fuel, gasoline, diesel, and the like), which have low-sulfur requirements and low-oxygen preferences. Further, the plastic pyrolysis oil described herein can be used as-produced (the total liquid product) or as a distilled fraction thereof depending on the end-product fuel.

[0009] Typically, fuels are blended with other hydrocarbon liquids to produce a blended fuel composition having desired properties. The blending hydrocarbons (e.g., light cycle oil and straight run automotive diesel) often are produced using catalytic cracking of crude oil or other fossil fuel sources. The present disclosure proposes to use plastic pyrolysis oil (total liquid product or fractions thereof) as the blending hydrocarbon. Blending hydrocarbons produced from crude oil and other fossil fuels can have high sulfur concentrations (depending on the source of the crude oil) but a lower cetane index, higher viscosity, and higher density as compared to the plastic pyrolysis oils described herein. Because of the lower cetane index, higher viscosity, and higher density, more fossil fuel-derived blending hydrocarbons (as compared to the plastic pyrolysis oils described herein) are needed to achieve the desired properties of the resultant blended fuel composition. However, the sulfur content can limit the amount of the fossil fuel-derived blending hydrocarbon that can be used. Alternatively, additional desulfurization must be performed before blending. Therefore, the plastic pyrolysis oils described herein provide low-sulfur advantages (e.g., more can be added, if needed, without exceeding the final composition sulfur specifications) as well as high cetane index, lower viscosity, and lower density advantages (e.g., less plastic pyrolysis

oil can be used to achieve the desired fuel properties). This provides enhanced versatility in the application of plastic pyrolysis oils in fuel blending. For example, naphtha, distillate, and heavy pyrolysis fuel fractions of the total liquid product of a plastic pyrolysis oil can be blended into gasoline, diesel, and marine fuel, respectively.

[0010] Other organic and biomass pyrolysis oils have been used in the production of fuel products. For example, pyrolysis of organic blendstocks like cellulose can produce broad boiling range hydrocarbon species. However, because of the blendstock composition, the resultant pyrolysis oil has a higher oxygen content, which limits the amount of said pyrolysis oil that can be included in the fuel product. In contrast, the plastic pyrolysis oil contains very low oxygen and sulfur, which allows for the plastic pyrolysis oil or a distillate thereof to be blended directly into fuel without additional purification (e.g., sulfur removal) and to be blended into the fuel at higher concentrations.

[0011] An additional benefit of the use of plastic pyrolysis oil is that the rigorous requirements for mechanical recycling (e.g., separation of each plastic type and stringent pre-cleaning) are not required. Rather, several types of plastic can be pyrolyzed simultaneously with little to no pre-cleaning because the organic matter (e.g., food) carried along with the plastic waste is also pyrolyzed.

Definitions and Test Methods

[0012] All numerical values within the detailed description and the claims herein are modified by “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

[0013] As used herein, a reference to a “C_x” fraction, stream, portion, feed, or other quantity is defined as a fraction (or other quantity) where 50 wt% or more of the fraction corresponds to hydrocarbons having “x” number of carbons. When a range is specified, such as “C_x-C_y,” 50 wt% or more of the fraction corresponds to hydrocarbons having a number of carbons from “x” to “y.” A specification of “C_x” (or “C_x”) corresponds to a fraction where 50 wt% or more of the fraction corresponds to hydrocarbons having the specified number of carbons or more (or the specified number of carbons or less).

[0014] As used herein, “plastic pyrolysis oil” refers to pyrolysis oil where at least 50 wt% of the pyrolysis oil is derived from a plastic source. That is, the feedstock (also referred to as plastic feedstock) that is pyrolyzed comprises at least 50 wt% plastic.

[0015] As used herein, the term “naphtha” or “naphtha fraction” refers to a hydrocarbon composition having an initial boiling point (ASTM D2887-19a using a using a 15-theoretical plate

column and 5:1 flux ratio is a classical method to obtain the distillation curve) of about -6°C to about 193°C.

[0016] As used herein, the term “distillate” or “distillate fraction” refers to a hydrocarbon composition having an initial boiling point (ASTM D2887-19a using a using a 15-theoretical plate column and 5:1 flux ratio is a classical method to obtain the distillation curve) of about 193°C to about 371°C.

[0017] As used herein, the term “heavy pyrolysis fuel” or “heavy pyrolysis fuel” refers to a hydrocarbon composition having an initial boiling point (ASTM D2887-19a using a using a 15-theoretical plate column and 5:1 flux ratio is a classical method to obtain the distillation curve) of about 371°C to about 561°C.

[0018] Herein, density is measured by ASTM D4052-18a measured at 15°C.

[0019] Herein, the sulfur content is measured by ASTM D2622-16.

[0020] Herein, the metal content (e.g., the amount of vanadium and other metals) is measured by inductively couple plasma methods.

[0021] Herein, cetane index is measured by ASTM D4737-10(2016) Procedure A.

[0022] Herein, kinematic viscosity is measured by ASTM D445-19.

[0023] Herein, solubility blending number (S_N) and insolubility number (I_N) are determined as described in US Patent No. 5,997,723, incorporated herein by reference.

[0024] Herein, flashpoint is measured by ASTM D6450-16a.

[0025] Herein, calculated carbon aromaticity index (CCAI) is determined according to Equation F.1 in ISO 8217:2012.

[0026] Herein, lubricity is measured by high frequency reciprocating rig (HFRR) using ASTM D6079-18.

[0027] Herein, NACE is a corrosion based test measured according to NACE Standard TM0172-2001.

Compositions and Methods

[0028] Methods of the present disclosure include mixing (or blending) a plastic pyrolysis oil (e.g., a total liquid product from a plastic pyrolysis process or a fraction of the total liquid product) with a fuel oil. Example combinations of plastic pyrolysis oils and blendstock fuels include, but are not limited to, a naphtha fraction of a plastic pyrolysis total liquid product and gasoline; a distillate fraction of a plastic pyrolysis total liquid product and diesel; a distillate fraction of a plastic pyrolysis total liquid product and marine fuel; a heavy pyrolysis fuel fraction of a plastic pyrolysis total liquid product and marine fuel; and a plastic pyrolysis total liquid product and marine fuel.

[0029] The amount of plastic pyrolysis oil (as the total liquid product or a fraction thereof) in a fuel may be about 20 vol% or less (or about 1 vol% to about 20 vol%, or about 1 vol% to about 15 vol%, or about 1 vol% to about 10 vol%, or about 1 vol% to about 5 vol%, or about 3 vol% to about 8 vol%, or about 10 vol% to about 20 vol%).

[0030] For example, a blended fuel composition of the present disclosure may comprise about 20 vol% or less (or about 1 vol% to about 20 vol%, or about 1 vol% to about 15 vol%, or about 1 vol% to about 10 vol%, or about 1 vol% to about 5 vol%, or about 3 vol% to about 8 vol%, or about 10 vol% to about 20 vol%) of a plastic pyrolysis total liquid product and about 80 vol% or more (or about 80 vol% to about 99 vol%, or about 85 vol% to about 99 vol%, or about 90 vol% to about 99 vol%, or about 95 vol% to about 99 vol%, or about 92 vol% to about 97 vol%, or about 80 vol% to about 90 vol%) of a marine fuel. Further, a method of the present disclosure may comprise mixing (or blending) a plastic pyrolysis total liquid product with a marine fuel in the foregoing amounts to produce a blended fuel composition.

[0031] In another example, a blended fuel composition of the present disclosure may comprise about 20 vol% or less (or about 1 vol% to about 20 vol%, or about 1 vol% to about 15 vol%, or about 1 vol% to about 10 vol%, or about 1 vol% to about 5 vol%, or about 3 vol% to about 8 vol%, or about 10 vol% to about 20 vol%) of a naphtha fraction of a plastic pyrolysis total liquid product and about 80 vol% or more (or about 80 vol% to about 99 vol%, or about 85 vol% to about 99 vol%, or about 90 vol% to about 99 vol%, or about 95 vol% to about 99 vol%, or about 92 vol% to about 97 vol%, or about 80 vol% to about 90 vol%) of a gasoline. Further, a method of the present disclosure may comprise mixing (or blending) a naphtha fraction of plastic pyrolysis total liquid product with a gasoline in the foregoing amounts to produce a blended fuel composition.

[0032] In yet another example, a blended fuel composition of the present disclosure may comprise about 20 vol% or less (or about 1 vol% to about 20 vol%, or about 1 vol% to about 15 vol%, or about 1 vol% to about 10 vol%, or about 1 vol% to about 5 vol%, or about 3 vol% to about 8 vol%, or about 10 vol% to about 20 vol%) of a distillate fraction of a plastic pyrolysis total liquid product and about 80 vol% or more (or about 80 vol% to about 99 vol%, or about 85 vol% to about 99 vol%, or about 90 vol% to about 99 vol%, or about 95 vol% to about 99 vol%, or about 92 vol% to about 97 vol%, or about 80 vol% to about 90 vol%) of a diesel. Further, a method of the present disclosure may comprise mixing (or blending) a distillate fraction of a plastic pyrolysis total liquid product with a diesel in the foregoing amounts to produce a blended fuel composition.

[0033] In another example, a blended fuel composition of the present disclosure may comprise about 20 vol% or less (or about 1 vol% to about 20 vol%, or about 1 vol% to about 15 vol%, or about 1 vol% to about 10 vol%, or about 1 vol% to about 5 vol%, or about 3 vol% to about 8 vol%,

or about 10 vol% to about 20 vol%) of a distillate fraction of a plastic pyrolysis total liquid product and about 80 vol% or more (or about 80 vol% to about 99 vol%, or about 85 vol% to about 99 vol%, or about 90 vol% to about 99 vol%, or about 95 vol% to about 99 vol%, or about 92 vol% to about 97 vol%, or about 80 vol% to about 90 vol%) of a marine fuel. Further, a method of the present disclosure may comprise mixing (or blending) a distillate fraction of a plastic pyrolysis total liquid product with a marine fuel in the foregoing amounts to produce a blended fuel composition.

[0034] In yet another example, a blended fuel composition of the present disclosure may comprise about 20 vol% or less (or about 1 vol% to about 20 vol%, or about 1 vol% to about 15 vol%, or about 1 vol% to about 10 vol%, or about 1 vol% to about 5 vol%, or about 3 vol% to about 8 vol%, or about 10 vol% to about 20 vol%) of a heavy pyrolysis fuel fraction of a plastic pyrolysis total liquid product and about 80 vol% or more (or about 80 vol% to about 99 vol%, or about 85 vol% to about 99 vol%, or about 90 vol% to about 99 vol%, or about 95 vol% to about 99 vol%, or about 92 vol% to about 97 vol%, or about 80 vol% to about 90 vol%) of a marine fuel. Further, a method of the present disclosure may comprise mixing (or blending) a heavy pyrolysis fuel fraction of a plastic pyrolysis total liquid product with a marine fuel in the foregoing amounts to produce a blended fuel composition.

[0035] The plastic pyrolysis oil may be produced on-site where the blending occurs or produced off-site and transported to the blending site.

[0036] Pyrolysis of the plastic feedstock may be performed by known methods and in known systems (e.g., at temperatures of 400°C to 850°C, or 400°C to 600°C, or 500°C to 850°C). The pyrolysis process produces a gas product stream and a liquid product stream (also referred to herein as the total liquid product). Optionally, the total liquid product is then distilled (or separated) into one or more fractions including, but not limited to, a naphtha fraction, a distillate fraction, and a heavy pyrolysis fuel fraction (e.g., comprising wax and non-distilled residue).

[0037] Examples of plastic sources include, but are not limited to, plastic waste (e.g., plastic straws, plastic utensils, plastic bags, food containers, plastic textiles, and the like), composite materials (e.g., composite packaging), waste streams, industrial scrap, municipal waste, and the like, and any combination thereof.

[0038] Said plastic sources may comprise one or more polymers that include, but are not limited to, polyolefins (e.g., homopolymer or copolymers of ethylene, propylene, butene, hexene, butadiene, isoprene, isobutylene, and other olefins), polystyrene, polyvinylchloride, polyamide (e.g., nylon), polyethylene terephthalate, polyurethane, ethylene vinyl acetate, and the like. While halogenated polymers, nitrogen-containing polymers, and oxygen-containing polymers may be

used, the inclusion of said polymers is preferably minimized so that the hydrocarbon content in the plastic pyrolysis oil is maximized. Other materials may be used in combination with the plastic source to produce the plastic pyrolysis oil, for example, paper, cardboard, textiles, tissues, and the like, and any combination thereof.

[0039] Preferably, the plastic portion of the plastic feedstock for pyrolysis may comprise polyolefin at 50 wt% or greater (or 65 wt% to 100 wt%, or 65 wt% to 80 wt%, or 75 wt% to 90 wt%, or 80 wt% to 100 wt%) with a balance of one or more other polymers.

[0040] A plastic pyrolysis total liquid product may have a density of about 0.75 g/mL to about 0.90 g/mL (or about 0.75 g/mL to about 0.85 g/mL, or about 0.80 g/mL to about 0.90 g/mL).

[0041] A plastic pyrolysis total liquid product may have a sulfur content of 100 ppm or less (or about 0.5 ppm to about 100 ppm, or about 0.5 ppm to about 50 ppm, or about 25 ppm to about 100 ppm).

[0042] A plastic pyrolysis total liquid product may have a kinematic viscosity at 50°C of about 1.0 mm²/s to about 3.0 mm²/s (or about 1.0 mm²/s to about 2.5 mm²/s, or about 2.0 mm²/s to about 3.0 mm²/s).

[0043] A plastic pyrolysis total liquid product may have a kinematic viscosity at 100°C of about 0.5 mm²/s to about 2.5 mm²/s (or about 0.5 mm²/s to about 1.5 mm²/s, or about 1.0 mm²/s to about 2.5 mm²/s).

[0044] A naphtha fraction of a plastic pyrolysis total liquid product may have a density of about 0.65 g/mL to about 0.80 g/mL (or about 0.65 g/mL to about 0.75 g/mL, or about 0.70 g/mL to about 0.80 g/mL).

[0045] A naphtha fraction of a plastic pyrolysis total liquid product may have a sulfur content of 100 ppm or less (or about 0.5 ppm to about 100 ppm, or about 0.5 ppm to about 50 ppm, or about 25 ppm to about 100 ppm).

[0046] A distillate fraction of a plastic pyrolysis total liquid product may have a density of about 0.70 g/mL to about 0.85 g/mL (or about 0.70 g/mL to about 0.80 g/mL, or about 0.75 g/mL to about 0.85 g/mL).

[0047] A distillate fraction of a plastic pyrolysis total liquid product may have a sulfur content of 100 ppm or less (or about 0.5 ppm to about 100 ppm, or about 0.5 ppm to about 50 ppm, or about 25 ppm to about 100 ppm).

[0048] A distillate fraction of a plastic pyrolysis total liquid product may have a cetane index of about 40 to about 80 (or about 40 to about 60, or about 60 to about 80).

[0049] A distillate fraction of a plastic pyrolysis total liquid product may have a kinematic viscosity at 40°C of about 0.75 mm²/s to about 4.5 mm²/s (or about 0.75 mm²/s to about 3.5 mm²/s, or about 2.5 mm²/s to about 4.5 mm²/s).

[0050] A distillate fraction of a plastic pyrolysis total liquid product may have a kinematic viscosity at 100°C of about 0.25 mm²/s to about 2.25 mm²/s (or about 0.25 mm²/s to about 1.5 mm²/s, or about 1.25 mm²/s to about 2.25 mm²/s).

[0051] A heavy pyrolysis fuel fraction of a plastic pyrolysis total liquid product may have a density of about 0.70 g/mL to about 0.90 g/mL (or about 0.70 g/mL to about 0.85 g/mL, or about 0.75 g/mL to about 0.90 g/mL).

[0052] A heavy pyrolysis fuel fraction of a plastic pyrolysis total liquid product may have a sulfur content of 150 ppm or less (or about 0.5 ppm to about 150 ppm, or about 0.5 ppm to about 75 ppm, or about 50 ppm to about 150 ppm).

[0053] A heavy pyrolysis fuel fraction of a plastic pyrolysis total liquid product may have a CCAI of about 750 to about 870 (or about 750 to about 825, or about 800 to about 870).

[0054] A heavy pyrolysis fuel fraction of a plastic pyrolysis total liquid product may have a kinematic viscosity at 50°C of about 3 mm²/s to about 20 mm²/s (or about 3 mm²/s to about 15 mm²/s, or about 10 mm²/s to about 20 mm²/s).

[0055] Tables 1 and 2 below disclose properties for light cycle oils (LCO) and straight run diesels (SRD) for comparison to the plastic pyrolysis oils described herein.

Table 1

Property	LCO 1	LCO 2
Density at 15 °C, g/mL	0.9219	0.9185
Water content, vol%	<0.05	
T50, °C	285	316
Appearance	ASTM Color 1.5	
Flash point, °C	87	
Sulfur content, ppm m/m	370	8280
Kinematic viscosity, cSt	6.3 at 20°C	4.246 at 50°C
Cetane Index	31	36.7

Table 2

Property	SRD 1	SRD 2
Acid Number, mg KOH/mg	0.111	0.448

Cloud Point, °C	-9	-15
Density, g/mL	0.836	0.8563
Flash, °C	60	82
Sulfur, ppm m/m	5939	10059
Viscosity, cSt	-	4.047 at 37.8 °C
Cetane Index	57.1	50.2
SIMDIST 10% Point, °C	218	237
SIMDIST 50% Point, °C	292	293
SIMDIST 90% Point, °C	349	341

[0056] The blended fuel composition produced by mixing the plastic pyrolysis total liquid product and the marine fuel may have properties desirable for a marine fuel. Said blended marine fuel properties may include one or more of the following: (a) a density of about 0.88 g/mL to about 1.1 g/mL; (b) a sulfur content of 3 wt% or less (or about 0.05 wt% to about 3 wt%); (c) a CCAI of about 750 to about 870; and (d) a kinematic viscosity at 50°C of about 5 mm²/s to about 700 mm²/s (or about 5 mm²/s to about 100 mm²/s, or about 50 mm²/s to about 250 mm²/s, or about 200 mm²/s to about 500 mm²/s, or about 400 mm²/s to about 700 mm²/s).

[0057] The blended fuel composition produced by mixing the naphtha fraction of a plastic pyrolysis total liquid product and the gasoline may have properties desirable for a gasoline. Said blended gasoline properties may include one or more of the following: (a) a density of about 0.7 g/mL to about 0.75 g/mL; and (b) a sulfur content of 100 ppm or less (or about 0.5 ppm to about 100 ppm, or about 0.5 ppm to about 50 ppm, or about 25 ppm to about 100 ppm).

[0058] The blended fuel composition produced by mixing the distillate fraction of a plastic pyrolysis total liquid product and the diesel may have properties desirable for a diesel. Said blended diesel properties may include one or more of the following: (a) a density of about 0.8 g/mL to about 0.87 g/mL; (b) a sulfur content of 0.002 wt% or less (or about 0.0002 wt% to about 0.002 wt%); (c) a cetane index of about 40 to about 60; and (d) a kinematic viscosity at 50°C of about 1.5 mm²/s to about 4.0 mm²/s (or about 1.5 mm²/s to about 3.0 mm²/s, or about 2.5 mm²/s to about 4.0 mm²/s).

[0059] The blended fuel composition produced by mixing the distillate fraction of a plastic pyrolysis total liquid product and the marine fuel may have properties desirable for a marine fuel. Said blended marine fuel properties may include one or more of the following: (a) a density of about 0.88 g/mL to about 1.1 g/mL; (b) a sulfur content of 3 wt% or less (or about 0.05 wt% to about 3 wt%); (c) a CCAI of about 750 to about 870; and (d) a kinematic viscosity at 50°C of about

5 mm²/s to about 700 mm²/s (or about 5 mm²/s to about 100 mm²/s, or about 50 mm²/s to about 250 mm²/s, or about 200 mm²/s to about 500 mm²/s, or about 400 mm²/s to about 700 mm²/s).

[0060] The blended fuel composition produced by mixing the heavy pyrolysis fuel fraction of a plastic pyrolysis total liquid product and the marine fuel may have properties desirable for a marine fuel. Said blended marine fuel properties may include one or more of the following: (a) a density of about 0.88 g/mL to about 1.1 g/mL; (b) a sulfur content of 3 wt% or less (or about 0.05 wt% to about 3 wt%); (c) a CCAI of about 750 to about 870; and (d) a kinematic viscosity at 50°C of about 5 mm²/s to about 700 mm²/s (or about 5 mm²/s to about 100 mm²/s, or about 50 mm²/s to about 250 mm²/s, or about 200 mm²/s to about 500 mm²/s, or about 400 mm²/s to about 700 mm²/s).

Example Embodiments

[0061] A first nonlimiting example embodiment of the present disclosure is a method comprising: blending a plastic pyrolysis oil with a blendstock fuel to produce a blended fuel composition, wherein the blended fuel composition comprises about 1 vol% to about 20 vol% of the plastic pyrolysis oil and about 80 vol% to about 99 vol% of the blendstock fuel, and wherein a combination of the plastic pyrolysis oil and the blendstock fuel is selected from the group consisting of: a naphtha fraction of the plastic pyrolysis total liquid product and gasoline; a distillate fraction of the plastic pyrolysis total liquid product and diesel; the distillate fraction of the plastic pyrolysis total liquid product and a marine fuel; a heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel; and the plastic pyrolysis total liquid product and the marine fuel.

[0062] A second nonlimiting example embodiment of the present disclosure is a blended fuel composition comprising: about 1 vol% to about 20 vol% of a plastic pyrolysis oil and about 80 vol% to about 99 vol% of the blendstock fuel, and wherein a combination of the plastic pyrolysis oil and the blendstock fuel is selected from the group consisting of: a naphtha fraction of the plastic pyrolysis total liquid product and gasoline; a distillate fraction of the plastic pyrolysis total liquid product and diesel; the distillate fraction of the plastic pyrolysis total liquid product and a marine fuel; a heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel; and the plastic pyrolysis total liquid product and the marine fuel.

[0063] The first and second nonlimiting example embodiment may further include one or more of: Element 1: wherein the blended fuel composition comprises about 5 vol% to about 10 vol% of the plastic pyrolysis oil and about 90 vol% to about 95 vol% of the blendstock fuel; Element 2: wherein the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the plastic pyrolysis total liquid product has one or more of the following properties: (a) a density of about 0.75 g/mL to about 0.90 g/mL; (b) a sulfur content of 100 ppm or less; (c) a kinematic viscosity at

50°C of about 1.0 mm²/s to about 3.0 mm²/s; and (d) a kinematic viscosity at 100°C of about 0.5 mm²/s to about 2.5 mm²/s; Element 3: Element 2 and wherein the combination is the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of about 0.88 g/mL to about 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of about 750 to about 870; and (d) a kinematic viscosity at 50°C of about 5 mm²/s to about 700 mm²/s; Element 4: wherein the naphtha fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the naphtha fraction has one or more of the following properties: (a) a density of about 0.65 g/mL to about 0.80 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of about 40 to about 80; (d) a kinematic viscosity at 50°C of about 0.5 mm²/s to about 2.5 mm²/s; and (e) a kinematic viscosity at 100°C of about 0.1 mm²/s to about 2.0 mm²/s; Element 5: Element 4 and wherein the combination is the naphtha fraction of the plastic pyrolysis total liquid product and the gasoline, and wherein the blended fuel composition has one or more of the following properties: (a) a density of about 0.7 g/mL to about 0.75 g/mL; and (b) a sulfur content of 100 ppm or less; Element 6: wherein the distillate fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the distillate fraction has one or more of the following properties: (a) a density of about 0.70 g/mL to about 0.85 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of about 40 to about 80; (d) a kinematic viscosity at 40°C of about 0.75 mm²/s to about 4.5 mm²/s; and (e) a kinematic viscosity at 100°C of about 0.25 mm²/s to about 2.25 mm²/s; Element 7: Element 6 and wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the diesel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of about 0.8 g/mL to about 0.87 g/mL; (b) a sulfur content of 0.002 wt% or less; (c) a cetane index of about 40 to about 60; and (d) a kinematic viscosity at 50°C of about 1.5 mm²/s to about 4.0 mm²/s; Element 8: Element 6 and wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of about 0.88 g/mL to about 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of about 750 to about 870; and (d) a kinematic viscosity at 50°C of about 5 mm²/s to about 700 mm²/s; Element 9: wherein the heavy pyrolysis fuel fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the heavy pyrolysis fuel fraction has one or more of the following properties: (a) a density of about 0.70 g/mL to about 0.90 g/mL; (b) a sulfur content of 150 ppm or less; (c) a CCAI of about 750 to about 870; and (d) a kinematic viscosity at 50°C of about 3 mm²/s to about 20 mm²/s; and Element 10: Element 9 and wherein the combination is the heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of

the following properties: (a) a density of about 0.88 g/mL to about 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of about 750 to about 870; and (d) a kinematic viscosity at 50°C of about 5 mm²/s to about 700 mm²/s. Examples of combinations include, but are not limited to, Element 1 in combination with Element 2 and optionally Element 3; Element 1 in combination with Element 4 and optionally Element 5; Element 1 in combination with Element 6 and optionally Element 7; Element 1 in combination with Element 6 and optionally Element 8; and Element 1 in combination with Element 9 and optionally Element 10.

[0064] Unless otherwise indicated, all numbers expressing quantities of ingredients, properties such as molecular weight, reaction conditions, and so forth used in the present specification and associated claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the embodiments of the present disclosure. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claim, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

[0065] One or more illustrative embodiments incorporating the disclosure embodiments disclosed herein are presented herein. Not all features of a physical implementation are described or shown in this application for the sake of clarity. It is understood that in the development of a physical embodiment incorporating the embodiments of the present disclosure, numerous implementation-specific decisions must be made to achieve the developer's goals, such as compliance with system-related, business-related, government-related and other constraints, which vary by implementation and from time to time. While a developer's efforts might be time-consuming, such efforts would be, nevertheless, a routine undertaking for those of ordinary skill in the art and having benefit of this disclosure.

[0066] While compositions and methods are described herein in terms of “comprising” various components or steps, the compositions and methods can also “consist essentially of” or “consist of” the various components and steps.

[0067] It is to be understood that while the disclosure has been described in conjunction with the specific embodiments thereof, the foregoing description is intended to illustrate and not limit the scope of the disclosure. Other aspects, advantages and modifications will be apparent to those skilled in the art to which the disclosure pertains.

[0068] To facilitate a better understanding of the embodiments of the present disclosure, the following examples of preferred or representative embodiments are given. In no way should the following examples be read to limit, or to define, the scope of the disclosure.

EXAMPLES

[0069] Tables 3-13 provide the properties an initial fuel oil (blendstock) and a pyrolyzed plastic oil used to produce a variety of blended fuel compositions, whose properties are also provided in Tables 3-13. More specifically, Tables 3-5 are blends of marine fuel having different sulfur contents with plastic pyrolysis total liquid product; Tables 6-8 are blends of marine fuel having different sulfur contents with the heavy fraction of plastic pyrolysis total liquid product; Tables 9-11 are blends of marine fuel having different sulfur contents with the distillate fraction of plastic pyrolysis total liquid product; Table 12 is a blend of diesel with the distillate fraction of plastic pyrolysis total liquid product; and Table 13 is a blend of gasoline with the naphtha fraction of plastic pyrolysis total liquid product.

Table 3

Property	High-Sulfur Marine Fuel	Plastic Pyrolysis Total Liquid Product	Blended Fuel Compositions (conc. of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	5 vol%	10 vol%	15 vol%
Density at 15 °C, g/mL	1.006	0.790	1.003	1.001	0.995	0.986	*0.973
Sulfur, wt%	2.59	0.007	2.55	2.53	2.47	2.39	*2.28
Viscosity at 50 °C, mm ² /s	487	1.50	*431	*383	*271	*160	*99
S _{BN}	110	13	111	121	95	90	*98
I _N	61	0	61	63	59	59	*61
S _{BN} -I _N	49	13	50	58	37	31	*37
TSE, wt%	0.08	0.01	0.07	0.07	0.06	0.05	-
TSP, wt%	0.09	0.02	0.08	0.07	0.07	0.06	-
Flash Point, °C	70	53	76	65	52	47	-
Vanadium, ppm	179	<0.345	*178	*176	*172	*165	*157
Aluminum + Silicon, ppm	35	<4	*35	*35	*34	*33	*31

Sodium, ppm	40	<4	*40	*39	*39	*37	*36
CCAI	863.9	737.2	*863	*861	*858	*851	*846

* Prophetic values based on trends seen in blending fuels.

Table 4

Property	Moderate-Sulfur Marine Fuel	Plastic Pyrolysis Total Liquid Product	Blended Fuel Compositions (conc. of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	5 vol%	10 vol%	15 vol%
Density at 15 °C, g/mL	0.9753	0.790	*0.973	*0.972	*0.966	*0.957	*0.948
Sulfur, wt%	0.842	0.007	*0.835	*0.828	*0.808	*0.773	*0.738
Viscosity at 50 °C, mm ² /s	1640	1.5	*1400	*1199	*768	*389	*211
S _{BN}	65.2	13	*65	*64	*63	*61	*59
I _N	40.5	0	*40.5	*40.5	*40.5	*40.5	*40.5
S _{BN} -I _N	24.7	13	*25	*24	*23	*21	*19
TSE, wt%	No data	0.01	-	-	-	-	-
TSP, wt%	0.05	0.02	-	-	-	-	-
Flash Point, °C	>140	53	-	-	-	-	-
Vanadium, ppm	26	<0.345	*26	*26	*25	*24	
Aluminum + Silicon, ppm	<15	<4	*<15	*<15	*<15	*<15	*<15
Sodium, ppm	4	<4	*<4	*<4	*<4	*<4	*<4
CCAI	825	737.2	*822	*821	*819	*814	*810

* Prophetic values based on trends seen in blending fuels.

Table 5

Property	Low-Sulfur Marine Fuel	Plastic Pyrolysis Total Liquid Product	Blended Fuel Compositions (conc. of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	5 vol%	10 vol%	15 vol%

Density at 15 °C, g/mL	0.9082	0.790	*0.907	*0.906	*0.902	*0.896	*0.891
Sulfur, wt%	0.072	0.007	*0.071	*0.071	*0.069	*0.066	*0.063
Viscosity at 50 °C, mm ² /s	33.95	1.50	*32.3	*30.7	*26.4	*20.9	*16.7
S _{BN}	52	13	*52	*51	*50	*49	*47
I _N	0	0	*0	*0	*0	*0	*0
S _{BN} -I _N	52	13	*52	*51	*50	*49	*47
TSE, wt%	No data	0.01	-	-	-	-	-
TSP, wt%	<0.01	0.02	-	-	-	-	-
Flash Point, °C	178.9	53	-	-	-	-	-
Vanadium, ppm	<0.35	<0.345	*<0.35	*<0.35	*<0.35	*<0.35	*<0.35
Aluminum + Silicon, ppm	Al < 2.79	<4	*Al <3	*Al <3	*Al <3	*Al <3	*Al <3
Sodium, ppm	<3.15	<4	*<4	*<4	*<4	*<4	*<4
CCAI	801	737.2	*800	*799	*798	*795	*792

* Prophetic values based on trends seen in blending fuels.

[0070] Tables 3-5 illustrate that viscosity of the marine fuel blendstock can be greatly reduced with as little as 1 vol% of plastic pyrolysis total liquid product. Further, high concentrations of plastic pyrolysis total liquid (e.g., 10 vol% to 15 vol%) reduces the sulfur content of the marine fuel. Further, these examples illustrate that the plastic pyrolysis total liquid product without further processing, which would typically be required of fossil fuel-derived blending hydrocarbons, can be included at concentrations of 15 vol% into marine fuels.

Table 6

Property	High-Sulfur Marine Fuel	Heavy Fraction of Plastic Pyrolysis Total Liquid Product	Blended Fuel Compositions (conc. of heavy fraction of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	5 vol%	10 vol%	15 vol%
Density at 15 °C, g/mL	1.006	0.836	1.005	1.006	0.998	0.986	*0.980

Sulfur, wt%	2.59	0.0106	2.57	2.60	2.50	2.34	*2.26
Viscosity at 50 °C, mm ² /s	487	8.74	*458	*430	*359	*269	*204
Viscosity at 100 °C, mm ² /s	41.39	3.251	45.932	47.219	39.262	30.476	-
S _{BN}	110	5	*109	*108	*105	98	*97
I _N	61	0	*61	*61	*61	61	*61
S _{BN} -I _N	49	5	*48	*47	*44	37	*36
TSE, wt%	0.08	-	-	-	-	-	-
TSP, wt%	0.09	0.36	-	-	-	-	-
Flash Point, °C	70	-	-	-	-	-	-
Vanadium, ppm	179	<0.5	*178	*176	*172	*164	*156
Aluminum + Silicon, ppm	35	<12	*35	*35	*34	*33	*32
Sodium, ppm	40	<5	*40	*39	*39	*37	*36
CCAI	863.9	755.5	*863.2	*862.1	*858.8	*853.4	*848.0

* Prophetic values based on trends seen in blending fuels.

Table 7

Property	Moderate-Sulfur Marine Fuel	Heavy Fraction of Plastic Pyrolysis Total Liquid Product	Blended Fuel Compositions (conc. of heavy fraction of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	5 vol%	10 vol%	15 vol%
Density at 15 °C, g/mL	0.9753	0.836	*0.974	*0.973	*0.968	*0.961	*0.954
Sulfur, wt%	0.842	0.0106	*0.835	*0.828	*0.806	*0.77	*0.733
Viscosity at 50 °C, mm ² /s	1640	8.74	*1503	*1379	*1070	*716	*490
S _{BN}	65.2	5	*65	*64	*63	*60	*57
I _N	40.5	0	*40.5	*40.5	*40.5	*40.5	*40.5
S _{BN} -I _N	24.7	5	*25		*23	*20	*17

TSE, wt%	No data	-	-	-	-	-	-
TSP, wt%	0.05	0.36	-	-	-	-	-
Flash Point, °C	>140	-	-	-	-	-	-
Vanadium, ppm	26	<0.5	*<26	*<26	*<26	*<26	*<26
Aluminum + Silicon, ppm	<15	<12	*<15	*<15	*<15	*<15	*<15
Sodium, ppm	4	<5	*<5	*<5	*<5	*<5	*<5
CCAI	825	755.5	*822	*821	*819	*816	*813

* Prophetic values based on trends seen in blending fuels.

Table 8

Property	Low-Sulfur Marine Fuel	Heavy Fraction of Plastic Pyrolysis Total Liquid Product	Blended Fuel Compositions (conc. of heavy fraction of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	5 vol%	10 vol%	15 vol%
Density at 15 °C, g/mL	0.9082	0.836	*0.908	*0.907	*0.905	*0.901	*0.897
Sulfur, wt%	0.072	0.0106	*0.071	*0.071	*0.069	*0.066	*0.063
Viscosity at 50 °C, mm ² /s	33.95	8.74	*33.40	*32.86	*31.30	*28.91	*26.74
S _{BN}	52	5	*52	*51	*50	*48	*45
I _N	0	0	*0	*0	*0	*0	*0
S _{BN} -I _N	52	5	*52	*51	*50	*48	*45
TSE, wt%	No data	-	-	-	-	-	-
TSP, wt%	<0.01	0.36	-	-	-	-	-
Flash Point, °C	178.9	-	-	-	-	-	-
Vanadium, ppm	<0.35	<0.5	*<0.5	*<0.5	*<0.5	*<0.5	*<0.5
Aluminum + Silicon, ppm	Al < 2.79	<12	*<5	*<5	*<5	*<5	*<5
Sodium, ppm	<3.15	<5	*<4	*<4	*<4	*<4	*<4

CCAI	801	755.5	*800	*800	*798	*796	*794
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* Prophetic values based on trends seen in blending fuels.

[0071] Tables 6-8 illustrate that viscosity of the marine fuel blendstock can be greatly reduced with as little as 1 vol% of the heavy fraction of plastic pyrolysis total liquid product. Further, high concentrations of the heavy fraction of plastic pyrolysis total liquid (e.g., 10 vol% to 15 vol%) reduces the sulfur content of the marine fuel. Additionally, these examples illustrate that the heavy fraction of a plastic pyrolysis total liquid product can be included at concentrations of 15 vol% into marine fuels.

Table 9

Property	High-Sulfur Marine Fuel	Distillate Fraction of Plastic Pyrolysis Total Liquid Product	Blended Fuel Compositions (conc. of heavy fraction of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	5 vol%	10 vol%	15 vol%
Density at 15 °C, g/mL	1.006	0.807	*1.004	*1.002	*0.996	*0.986	*0.976
Sulfur, wt%	2.59	0.005	*2.57	*2.55	*2.49	*2.38	*2.27
Viscosity at 50 °C, mm ² /s	487	2.35	*439	*397	*296	*187	*123
S _{DN}	110	-	-	-	-	-	-
I _N	61	-	-	-	-	-	-
S _{BN} -I _N	49	-	-	-	-	-	-
TSE, wt%	0.08	-	-	-	-	-	-
TSP, wt%	0.09	-	-	-	-	-	-
Flash Point, °C	70	84	-	-	-	-	-
Vanadium, ppm	179	-	-	-	-	-	-
Aluminum + Silicon, ppm	35	-	-	-	-	-	-
Sodium, ppm	40	-	-	-	-	-	-
CCAI	863.9	770	*863	*862	*860	*855	*850

* Prophetic values based on trends seen in blending fuels.

Table 10

Property	Moderate-Sulfur Marine Fuel	Distillate Fraction of Plastic Pyrolysis Total Liquid Product	Blended Fuel Compositions (conc. of heavy fraction of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	5 vol%	10 vol%	15 vol%
Density at 15 °C, g/mL	0.9753	0.807	*0.974	*0.972	*0.967	*0.959	*0.95
Sulfur, wt%	0.842	0.005	*0.835	*0.828	*0.807	*0.772	*0.735
Viscosity at 50 °C, mm ² /s	1640	2.35	*1432	*1253	*852	*469	*272
S _{BN}	65.2	-	-	-	-	-	-
I _N	40.5	-	-	-	-	-	-
S _{BN} -I _N	24.7	-	-	-	-	-	-
TSE, wt%	No data	-	-	-	-	-	-
TSP, wt%	0.05	-	-	-	-	-	-
Flash Point, °C	>140	84	-	-	-	-	-
Vanadium, ppm	26	-	-	-	-	-	-
Aluminum + Silicon, ppm	<15	-	-	-	-	-	-
Sodium, ppm	4	-	-	-	-	-	-
CCAI	825	770	*822	*822	*820	*818	*815

* Prophetic values based on trends seen in blending fuels.

Table 11

Property	Low-Sulfur Marine Fuel	Distillate Fraction of Plastic Pyrolysis	Blended Fuel Compositions (conc. of heavy fraction of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	5 vol%	10 vol%	15 vol%

		Total Liquid Product					
Density at 15 °C, g/mL	0.9082	0.807	*0.907	*0.906	*0.903	*0.898	*0.893
Sulfur, wt%	0.072	0.005	*0.071	*0.071	*0.069	*0.066	*0.063
Viscosity at 50 °C, mm ² /s	33.95	2.35	*32.61	*31.33	27.85	*23.07	*19.29
S _{BN}	52	-	-	-	-	-	-
I _N	0	-	-	-	-	-	-
S _{BN} -I _N	52	-	-	-	-	-	-
TSE, wt%	No data	-	-	-	-	-	-
TSP, wt%	<0.01	-	-	-	-	-	-
Flash Point, °C	178.9	84	-	-	-	-	-
Vanadium, ppm	<0.35	-	-	-	-	-	-
Aluminum + Silicon, ppm	Al < 2.79	-	-	-	-	-	-
Sodium, ppm	<3.15	-	-	-	-	-	-
CCAI	801	770	*800	*800	*799	*798	*796

* Prophetic values based on trends seen in blending fuels.

[0072] Tables 9-11 illustrate that viscosity of the marine fuel blendstock can be greatly reduced with as little as 1 vol% of the distillate fraction of plastic pyrolysis total liquid product. Further, high concentrations of the distillate fraction of plastic pyrolysis total liquid (e.g., 10 vol% to 15 vol%) reduces the sulfur content of the marine fuel. Additionally, these examples illustrate that the distillate fraction of a plastic pyrolysis total liquid product can be included at concentrations of 15 vol% into marine fuels.

Table 12

Property	Ultra-Low Sulfur Diesel	Distillate Fraction of Plastic Pyrolysis	Blended Fuel Compositions (conc. of distillate fraction of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2 vol%	2.5 vol%	5 vol%	10 vol%

		Total Liquid Product					
Flash, °C	69	84	61	-	-	65	64
Density at 15 °C, g/mL	0.839	0.807	0.835	0.838	-	0.837	0.836
Washed Gums, mg/100 mL	0.5	-	0.0	-	-	-	0.0
NACE	D	A	C	-	-	-	B
Lubricity, micron	560	170	510	440	-	380	340
Cloud, °C	-7	5	-7	-7	-	-7	-7
Pour, °C	-18	-	-21	-12	-	-18	-12
Distillation T10, °C	194	224	188	192	-	193	193
Distillation T50, °C	262	295	252	261	-	261	262
Distillation T90, °C	334	348	329	334	-	333	332
Sulfur, ppm	9.4	50.3	8.2	9.3	-	10.3	14.1
Viscosity, at 40 °C, mm ² /s	2.460	2.642	2.310	2.460	-	2.470	2.480
Cetane Index	49	73.4	48	49	-	49	50
Filter Blocking Tendency	1.02	-	1.11	1.09	1.13	-	5.10

- Not measured

[0073] Table 12 illustrates that a distillate fraction of plastic pyrolysis total liquid product can be blended with an ultra-low sulfur diesel to increase the cetane index and decrease the density while minimally increasing the sulfur content. In contrast, fossil fuel-derived blending hydrocarbons would likely need to undergo significant and costly desulfurization to be used with ultra-low sulfur diesel. Further, said fossil fuel-derived blending hydrocarbons would likely have a higher density (e.g., Table 1 and Table 2) and the reduction in density benefits of Table 3 would not be realized.

Table 13

Property	Gasoline	Naphtha Fraction of Plastic Pyrolysis Total Liquid Product	Blended Fuel Compositions (conc. of naphtha fraction of plastic pyrolysis total liquid product by total volume of the blend)				
			1 vol%	2.5 vol%	5 vol%	7.5 vol%	10 vol%
Density at 15 °C, g/mL	0.734	0.744	0.732	0.740	0.732	0.735*	0.735*
Washed Gums, mg/100 mL	1.5	10.0	0.2	1.5	0.4	~	~
Oxidative Stability, min	>240	<55	>240	>240	>240	>1000	>1000

[0074] Table 13 illustrates that the naphtha fraction of plastic pyrolysis total liquid product can be blended with gasoline fuel to reduce the density.

[0075] Tables 3-13 illustrate that plastic pyrolysis (total liquid product or a fraction thereof) can be blended with a variety of blendstock fuels (e.g., marine fuel, naphtha fuel, and diesel) in varying concentrations, including at 15 vol%, to tune the density, viscosity, and other properties while producing a blended fuel with an acceptable low sulfur content (which in many cases is a reduced sulfur content).

[0076] Therefore, the present disclosure is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present disclosure may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope and spirit of the present disclosure. The disclosure illustratively disclosed herein suitably may be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While compositions and methods are described in terms of “comprising,” “containing,” or “including” various components or steps, the compositions and methods can also “consist essentially of” or “consist of” the various

components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the elements that it introduces.

[0077] PCT/EP Clauses:

[0078] 1. A method of making a blended fuel composition comprising: blending a plastic pyrolysis oil with a blendstock fuel to produce a blended fuel composition, wherein the blended fuel composition comprises 1 vol% to 20 vol% of the plastic pyrolysis oil and 80 vol% to 99 vol% of the blendstock fuel, and wherein a combination of the plastic pyrolysis oil and the blendstock fuel is selected from the group consisting of: a naphtha fraction of the plastic pyrolysis total liquid product and gasoline; a distillate fraction of the plastic pyrolysis total liquid product and diesel; the distillate fraction of the plastic pyrolysis total liquid product and a marine fuel; a heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel; and, the plastic pyrolysis total liquid product and the marine fuel.

[0079] 2. The method of clause 1, wherein the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the plastic pyrolysis total liquid product has one or more of the following properties: (a) a density of 0.75 g/mL to 0.90 g/mL; (b) a sulfur content of 100 ppm or less; (c) a kinematic viscosity at 50°C of 1.0 mm²/s to 3.0 mm²/s; and (d) a kinematic viscosity at 100°C of 0.5 mm²/s to 2.5 mm²/s.

[0080] 3. The method of clause 2, wherein the combination is the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.

[0081] 4. The method of clause 1, wherein the naphtha fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the naphtha fraction has one or more of the following properties: (a) a density of 0.65 g/mL to 0.80 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of 40 to 80; (d) a kinematic viscosity at 50°C of 0.5 mm²/s to 2.5 mm²/s; and (e) a kinematic viscosity at 100°C of 0.1 mm²/s to 2.0 mm²/s.

[0082] 5. The method of clause 4, wherein the combination is the naphtha fraction of the plastic pyrolysis total liquid product and the gasoline, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.7 g/mL to 0.75 g/mL; and (b) a sulfur content of 100 ppm or less.

[0083] 6. The method of clause 1, wherein the distillate fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the distillate fraction has one or more of the following properties: (a) a density of 0.70 g/mL to 0.85 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of 40 to 80; (d) a kinematic viscosity at 40°C of 0.75 mm²/s to 4.5 mm²/s; and (e) a kinematic viscosity at 100°C of 0.25 mm²/s to 2.25 mm²/s.

[0084] 7. The method of clause 6, wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the diesel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.8 g/mL to 0.87 g/mL; (b) a sulfur content of 0.002 wt% or less; (c) a cetane index of 40 to 60; and (d) a kinematic viscosity at 50°C of 1.5 mm²/s to 4.0 mm²/s.

[0085] 8. The method of clause 6, wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.

[0086] 9. The method of clause 1, wherein the heavy pyrolysis fuel fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the heavy pyrolysis fuel fraction has one or more of the following properties: (a) a density of 0.70 g/mL to 0.90 g/mL; (b) a sulfur content of 150 ppm or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 3 mm²/s to 20 mm²/s.

[0087] 10. The method of clause 9, wherein the combination is the heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.

[0088] 11. A blended fuel composition comprising: 1 vol% to 20 vol% of a plastic pyrolysis oil and 80 vol% to 99 vol% of the blendstock fuel, and wherein a combination of the plastic pyrolysis oil and the blendstock fuel is selected from the group consisting of: a naphtha fraction of the plastic pyrolysis total liquid product and gasoline; a distillate fraction of the plastic pyrolysis total liquid product and diesel; the distillate fraction of the plastic pyrolysis total liquid product and

a marine fuel; a heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel; and the plastic pyrolysis total liquid product and the marine fuel.

[0089] 12. The blended fuel composition of clause 11, wherein the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the plastic pyrolysis total liquid product has one or more of the following properties: (a) a density of 0.75 g/mL to 0.90 g/mL; (b) a sulfur content of 100 ppm or less; (c) a kinematic viscosity at 50°C of 1.0 mm²/s to 3.0 mm²/s; and (d) a kinematic viscosity at 100°C of 0.5 mm²/s to 2.5 mm²/s.

[0090] 13. The blended fuel composition of clause 12, wherein the combination is the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.

[0091] 14. The blended fuel composition of clause 11, wherein the naphtha fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein naphtha fraction has one or more of the following properties: (a) a density of 0.65 g/mL to 0.80 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of 40 to 80; (d) a kinematic viscosity at 50°C of 0.5 mm²/s to 2.5 mm²/s; and (e) a kinematic viscosity at 100°C of 0.1 mm²/s to 2.0 mm²/s.

[0092] 15. The blended fuel composition of clause 16, wherein the combination is the naphtha fraction of the plastic pyrolysis total liquid product and the gasoline, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.7 g/mL to 0.75 g/mL; and (b) a sulfur content of 100 ppm or less.

[0093] 16. The blended fuel composition of clause 11, wherein the distillate fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the distillate fraction has one or more of the following properties: (a) a density of 0.70 g/mL to 0.85 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of 40 to 80; (d) a kinematic viscosity at 40°C of 0.75 mm²/s to 4.5 mm²/s; and (e) a kinematic viscosity at 100°C of 0.25 mm²/s to 2.25 mm²/s.

[0094] 17. The blended fuel composition of clause 16, wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the diesel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.8 g/mL to 0.87 g/mL; (b) a sulfur content of 0.002 wt% or less; (c) a cetane index of 40 to 60; and (d) a kinematic viscosity at 50°C of 1.5 mm²/s to 4.0 mm²/s.

[0095] 18. The blended fuel composition of clause 16, wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of about 0.88 g/mL to

about 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of about 750 to about 870; and (d) a kinematic viscosity at 50°C of about 5 mm²/s to about 700 mm²/s.

[0096] 19. The blended fuel composition of clause 11, wherein the heavy pyrolysis fuel fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and the heavy pyrolysis fuel fraction has one or more of the following properties: (a) a density of 0.70 g/mL to 0.90 g/mL; (b) a sulfur content of 150 ppm or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 3 mm²/s to 20 mm²/s.

[0097] 20. The blended fuel composition of clause 19, wherein the combination is the heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.

CLAIMS

What is claimed is:

1. A method of making a blended fuel composition comprising: blending a plastic pyrolysis oil with a blendstock fuel to produce a blended fuel composition, wherein the blended fuel composition comprises 1 vol% to 20 vol% of the plastic pyrolysis oil and 80 vol% to 99 vol% of the blendstock fuel, and wherein a combination of the plastic pyrolysis oil and the blendstock fuel is selected from the group consisting of: a naphtha fraction of the plastic pyrolysis total liquid product and gasoline; a distillate fraction of the plastic pyrolysis total liquid product and diesel; the distillate fraction of the plastic pyrolysis total liquid product and a marine fuel; a heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel; and, the plastic pyrolysis total liquid product and the marine fuel.

2. The method of claim 1, wherein the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the plastic pyrolysis total liquid product has one or more of the following properties: (a) a density of 0.75 g/mL to 0.90 g/mL; (b) a sulfur content of 100 ppm or less; (c) a kinematic viscosity at 50°C of 1.0 mm²/s to 3.0 mm²/s; and (d) a kinematic viscosity at 100°C of 0.5 mm²/s to 2.5 mm²/s.

3. The method of claim 2, wherein the combination is the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.

4. The method of claim 1, wherein the naphtha fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the naphtha fraction has one or more of the following properties: (a) a density of 0.65 g/mL to 0.80 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of 40 to 80; (d) a kinematic viscosity at 50°C of 0.5 mm²/s to 2.5 mm²/s; and (e) a kinematic viscosity at 100°C of 0.1 mm²/s to 2.0 mm²/s.

5. The method of claim 4, wherein the combination is the naphtha fraction of the plastic pyrolysis total liquid product and the gasoline, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.7 g/mL to 0.75 g/mL; and (b) a sulfur content of 100 ppm or less.

6. The method of claim 1, wherein the distillate fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the distillate fraction has one or more of the following properties: (a) a density of 0.70 g/mL to 0.85 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of 40 to 80; (d) a kinematic viscosity at 40°C of 0.75 mm²/s to 4.5 mm²/s; and (e) a kinematic viscosity at 100°C of 0.25 mm²/s to 2.25 mm²/s.

7. The method of claim 6, wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the diesel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.8 g/mL to 0.87 g/mL; (b) a sulfur content of 0.002 wt% or less; (c) a cetane index of 40 to 60; and (d) a kinematic viscosity at 50°C of 1.5 mm²/s to 4.0 mm²/s.

8. The method of claim 6, wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.

9. The method of claim 1, wherein the heavy pyrolysis fuel fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the heavy pyrolysis fuel fraction has one or more of the following properties: (a) a density of 0.70 g/mL to 0.90 g/mL; (b) a sulfur content of 150 ppm or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 3 mm²/s to 20 mm²/s.

10. The method of claim 9, wherein the combination is the heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.

11. A blended fuel composition comprising: 1 vol% to 20 vol% of a plastic pyrolysis oil and 80 vol% to 99 vol% of the blendstock fuel, and wherein a combination of the plastic pyrolysis oil and the blendstock fuel is selected from the group consisting of: a naphtha fraction of the plastic pyrolysis total liquid product and gasoline; a distillate fraction of the plastic pyrolysis total liquid product and diesel; the distillate fraction of the plastic pyrolysis total liquid product and a marine fuel; a heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel; and the plastic pyrolysis total liquid product and the marine fuel.

12. The blended fuel composition of claim 11, wherein the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the plastic pyrolysis total liquid product has one or more of the following properties: (a) a density of 0.75 g/mL to 0.90 g/mL; (b) a sulfur content of 100 ppm or less; (c) a kinematic viscosity at 50°C of 1.0 mm²/s to 3.0 mm²/s; and (d) a kinematic viscosity at 100°C of 0.5 mm²/s to 2.5 mm²/s.

13. The blended fuel composition of claim 12, wherein the combination is the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has

one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.

14. The blended fuel composition of claim 11, wherein the naphtha fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein naphtha fraction has one or more of the following properties: (a) a density of 0.65 g/mL to 0.80 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of 40 to 80; (d) a kinematic viscosity at 50°C of 0.5 mm²/s to 2.5 mm²/s; and (e) a kinematic viscosity at 100°C of 0.1 mm²/s to 2.0 mm²/s.

15. The blended fuel composition of claim 11, wherein the combination is the naphtha fraction of the plastic pyrolysis total liquid product and the gasoline, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.7 g/mL to 0.75 g/mL; and (b) a sulfur content of 100 ppm or less.

16. The blended fuel composition of claim 11, wherein the distillate fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and wherein the distillate fraction has one or more of the following properties: (a) a density of 0.70 g/mL to 0.85 g/mL; (b) a sulfur content of 100 ppm or less; (c) a cetane index of 40 to 80; (d) a kinematic viscosity at 40°C of 0.75 mm²/s to 4.5 mm²/s; and (e) a kinematic viscosity at 100°C of 0.25 mm²/s to 2.25 mm²/s.

17. The blended fuel composition of claim 16, wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the diesel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of 0.8 g/mL to 0.87 g/mL; (b) a sulfur content of 0.002 wt% or less; (c) a cetane index of 40 to 60; and (d) a kinematic viscosity at 50°C of 1.5 mm²/s to 4.0 mm²/s.

18. The blended fuel composition of claim 16, wherein the combination is the distillate fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein the blended fuel composition has one or more of the following properties: (a) a density of about 0.88 g/mL to about 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of about 750 to about 870; and (d) a kinematic viscosity at 50°C of about 5 mm²/s to about 700 mm²/s.

19. The blended fuel composition of claim 11, wherein the heavy pyrolysis fuel fraction of the plastic pyrolysis oil is the plastic pyrolysis total liquid product, and the heavy pyrolysis fuel fraction has one or more of the following properties: (a) a density of 0.70 g/mL to 0.90 g/mL; (b) a sulfur content of 150 ppm or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 3 mm²/s to 20 mm²/s.

20. The blended fuel composition of claim 19, wherein the combination is the heavy pyrolysis fuel fraction of the plastic pyrolysis total liquid product and the marine fuel, and wherein

the blended fuel composition has one or more of the following properties: (a) a density of 0.88 g/mL to 1.1 g/mL; (b) a sulfur content of 3 wt% or less; (c) a CCAI of 750 to 870; and (d) a kinematic viscosity at 50°C of 5 mm²/s to 700 mm²/s.