described above. Typical riser residence times are about 2 to 3 seconds and the additional termination system residence time may be about 1 to 2 seconds. This leads to an overall catalyst contact time of about 3 to 5 seconds.

[0020] One innovative embodiment that forms part of the present application may be to processes employing thermally-produced liquids in conjunction with petroleum based materials in FCCs or field upgrader operations. For example, a method that includes the co-processing of an non-hydrotreated biomass derived liquid in small amounts with VGO or other crude oil based liquids in the FCC or field upgrader operations.

[0021] Another innovative embodiment that forms part of the present application may be for biomass conversion that the prior art has overlooked and intentionally avoided: the co-processing of non-upgraded, thermally-produced liquid with hydrocarbons in a manner which removes the complexity of intermediate upgrading steps and yet may be still compatible with crude oil feedstock processing. As already indicated, the prior art has clearly shown that non-treated, thermally-produced biomass liquids are not suitable for conversion to liquid hydrocarbons directly in FCC and other catalytic conversion systems. Therefore when various schemes of co-processing with petroleum in existing refinery operations are considered in the prior art, including FCC co-processing, the co-processing of non-upgraded, non-treated thermal biomass liquids may be excluded from these co-processing options (Mercader; Fogassy). However, as set forth in the present disclosure, unexpected technical and economic benefits are in fact evident in the co-processing of thermally-derived biomass products with petroleum feedstocks in various refinery operations.

SUMMARY

[0022a] In one aspect, the disclosure refers to a method of preparing a fuel comprising co-processing in a fluidized catalytic cracking unit (FCC) a petroleum fraction feedstock with a renewable fuel oil feedstock in the presence of a catalyst, wherein the renewable fuel oil is an unenriched renewable fuel oil formed from ground-up biomass by a rapid thermal processing, wherein the unenriched renewable fuel oil does not undergo any further pre- or postprocessing including no hydrodeoxygenation, no hydrotreating, no catalytic exposure or contact, wherein the renewable fuel oil includes all of the whole liquid produced from the thermomechanical conversion of the biomass, wherein the unenriched renewable fuel oil is used in an amount of less than 6 wt.%, less than about 5 wt.% or less than about 3 wt.% relative to the total weight of feedstock fed, and wherein the petroleum fraction feedstock comprising a gas oil (GO) feedstock, a vacuum gas oil (VGO) feedstock, or a heavy gas oil (HGO) feedstock.

[0022] In certain examples, the disclosure relates a fuel composition derived from a petroleum fraction feedstock and a renewable fuel oil feedstock. In certain examples, the disclosure relates a fuel composition derived from a petroleum fraction feedstock and a renewable fuel oil feedstock co-processed in the presence of a catalyst. In certain examples, the disclosure relates a fluidized catalytic cracker product composition derived from a feedstock comprising a renewable fuel oil. In certain examples, the disclosure relates a fuel composition derived from greater than 80 wt.% of a petroleum fraction feedstock and less than 20 wt.% of a renewable fuel oil feedstock that may have been processed in conversion unit, in the presence of a catalyst.

[0023] In certain examples, the disclosure relates to a fuel comprising a product of a conversion unit, such as a fluidized catalytic cracker, having a petroleum fraction and a renewable fuel oil as reactants. In certain examples the disclosure relates to fuel comprising a product of

a refinery conversion unit co-processing a petroleum fraction jointly with a renewable fuel oil. In certain examples, the disclosure relates to a fuel comprising a product of a refinery conversion unit wherein the conversion unit receives a petroleum fraction and a renewable fuel oil.

[0024] In certain examples, the disclosure relates to a method of preparing a fuel, for example a transportation fuel, comprising providing a renewable fuel oil feedstock with a petroleum fraction feedstock in the presence of a catalyst. In certain examples, the disclosure relates to a method of preparing a fuel, comprising processing a petroleum fraction feedstock with a renewable fuel oil feedstock in the presence of a catalyst.

[0025] In certain examples, the disclosure relates to a method of preparing a fuel comprising processing a petroleum fraction feedstock with a renewable fuel oil feedstock in the presence of a catalyst and, optionally, adjusting feed addition rates of the petroleum fraction feedstock, the renewable fuel oil feedstock, or both, to target a particular fuel product profile, riser temperature, or reaction zone temperature; and/or, optionally, adjusting catalyst to combined petroleum fraction feedstock and renewable fuel oil feedstock ratio (catalyst:oil ratio) to target a particular fuel product profile, riser temperature, or reaction zone temperature; wherein the catalyst:oil ratio is a weight ratio or a volume ratio.

In certain examples, the disclosure relates to a method of co-processing a petroleum fraction feedstock and a renewable fuel oil such that the fuel product has at least 70 vol.% of gasoline and LCO or at least 70 vol.% of transportation fuel, relative to the total volume of product resulting from the product stream of the conversion unit.

In certain examples, the disclosure relates to a method of improving petroleum conversion in a refinery, comprising processing a petroleum fraction substituted with a renewable fuel oil (on an equivalent energy basis and/or carbon content basis) in the presence of a catalyst.

[0026] In certain examples, the disclosure relates to a method of increasing fuel yield, for example the yield of one or more of gasoline, diesel fuel, LPG, LCO, heating oil, and/or jet fuel, from conversion of a petroleum fraction feedstock, comprising processing a petroleum fraction feedstock with a renewable fuel oil feedstock in the presence of a catalyst.

[0027] In certain examples, the disclosure relates a fluidized catalytic cracker apparatus comprising a riser having a petroleum fraction injection port and a renewable fuel injection port or a riser that has been retro-fitted to add an element to allow for the injection of renewable fuel. In certain examples, the disclosure relates a refinery system, comprising a first assembly for introduction of a petroleum fraction feedstock; and a second assembly for introduction of a renewable fuel oil feedstock or has been retro-fitted to add the same. In certain examples, the disclosure relates a refinery system, comprising a first assembly for introduction of a petroleum fraction feedstock; and a second assembly for introduction of a renewable fuel oil feedstock into the conversion unit of the refinery or has been retro-fitted or adapted to add the same.

[0028] In certain examples, the disclosure relates to one or more units (for example a conversion unit) in a refinery system suitable for accepting a renewable fuel oil feedstock, comprising an installed independent port for introducing the renewable fuel oil feedstock. In certain examples, the disclosure relates to refinery system comprising an additional or modified riser assembly suitable for accepting the renewable fuel oil, for example an independent port comprising a nozzle; a separate or independent tankage for introducing the renewable fuel oil feedstock; an installed, re-calibrated, or modified or independent control or control system; and/or an installed live-tap for introducing the renewable fuel oil feedstock.

[0029] In certain examples, the disclosure relates a method of increasing mix-zone temperature in an FCC unit comprising injecting between 0.05-15 wt.% renewable fuel oil feedstock via a quench riser system downstream (after) of the introduction of a petroleum fraction feedstock injection nozzle.

[0030] In certain examples, the disclosure relates to a method of co-processing a renewable fuel oil; that has a carbon content level in the range of between 35-80 wt.%, on a dry basis moisture-free basis and/or an energy content level of at least 30 % of the energy content contained in the biomass from which it is derived; and a petroleum fraction feedstock; that comprises a gas oil (GO) feedstock, a vacuum gas oil (VGO) feedstock, a heavy gas oil (HGO) feedstock, a middle distillate feedstock, a heavy-middle distillate feedstock, a hydrocarbon-based feedstock, or combinations thereof; by introducing the renewable fuel oil and the petroleum gas fraction feedstock into a conversion unit wherein they have contact with a catalyst.

In certain examples, the disclosure relates to a fuel (for example diesel fuel and/or gasoline) producing pathway for generating cellulosic renewable identification numbers comprising converting a cellulosic feedstock via rapid thermal processing to form a renewable fuel oil and co-processing a petroleum fraction feedstock with the renewable fuel oil in the presence of a catalyst to produce a cellulosic renewable identification number-compliant fuel. In certain examples, the disclosure relates a diesel fuel and/or gasoline producing pathway for generating cellulosic renewable identification numbers comprising thermally converting a renewable [cellulosic] biomass feedstock to form a renewable fuel oil and co-processing a petroleum fraction feedstock with the renewable fuel oil in a refinery to produce a diesel fuel and/or gasoline that complies with a fuel pathway specified in U.S. renewable fuel standard program (RFS) regulations for generating the cellulosic renewable identification number. In certain examples, the disclosure relates to a fuel producing pathway for generating cellulosic renewable identification numbers comprising thermally processing a cellulosic feedstock via rapid thermal processing to form an unenriched renewable fuel oil and processing a petroleum fraction feedstock with the unenriched renewable fuel oil in a refinery to produce a unit of diesel fuel

sufficient to generate greater than 0.5 units of a cellulosic renewable identification number-compliant fuel.

[0031] In certain examples, the disclosure relates to a transportation fuel comprising a product resulting from the catalyitic conversion of a mixture comprising greater than 90 wt.% of a petroleum fraction feedstock and less than 10 wt.% of an unenriched renewable fuel oil feedstock derived from biomass (for example a cellulosic biomass).

[0032] In certain examples, the disclosure relates to a method of preparing a cellulosic renewable identification number qualifying-fuel comprising, optionally, forming a renewable fuel oil via rapid thermal processing of a renewable cellulosic biomass feedstock; injecting greater than 90 wt.% of a petroleum fraction feedstock into a refinery process; injecting less than 10 wt.% of the renewable fuel oil into the refinery process proximate the injection point of the petroleum fraction feedstock; and co-processing the petroleum fraction feedstock and renewable fuel oil to produce the cellulosic-renewable identification number qualifying-fuel; wherein the renewable fuel oil has a pH of 1.5-6, a solids content of less than 2.5 wt.%, and a water content of 20-45 wt.%.

[0033] In certain examples, the disclosure relates to a method of preparing a fuel derived at least in part from a renewable fuel processed through a refinery conversion unit, for example an FCC. In certain examples, the disclosure relates to a method of preparing a fuel derived at least in part from a renewable fuel having a pH of 1.5-6 and a water content of 20-45 wt.%, that has been processed through a refinery conversion unit, for example an FCC.

[0034] In certain examples, the disclosure relates to a method of producing a combustible fuel via a fuel pathway compliant with U.S. renewable fuel standard program regulations for generating renewable identification numbers, wherein the method comprises thermally converting cellulosic-based biomass into a renewable fuel oil such that the carbon content of the renewable fuel oil is less than 60 wt.% and has a pH of 1.5-8. In certain examples, the disclosure relates to a method of producing a combustible fuel via a fuel pathway compliant with U.S. renewable fuel standard program regulations for generating renewable identification numbers, wherein the method comprises thermally converting cellulosic-based biomass into a renewable fuel oil such that the carbon content of the renewable fuel oil is greater than at least 80 wt.% of the carbon content of the cellulosic-based biomass. In certain examples, the disclosure relates to a method of producing a combustible fuel via a fuel pathway compliant with U.S. renewable fuel standard program regulations for generating renewable identification numbers, wherein the method comprises thermally converting cellulosic-based biomass into a renewable fuel oil and co-processing a portion of the renewable fuel oil with greater than 90 wt.% of a non-hydrotreated gas oil feedstock to produce the combustible fuel.

[0035] In certain examples, the disclosure relates to a fuel composition derived at least in part from a petroleum fraction feedstock and a renewable fuel oil feedstock wherein the petroleum

feedstock and renewable fuel oil feedstock have been co-processed in the presence of a catalyst. In certain examples, the disclosure relates to a fluidized catalytic cracker product composition derived from a feedstock comprising a renewable fuel oil.

In certain examples, the disclosure relates to a method of preparing a fuel comprising processing a petroleum fraction feedstock with a renewable fuel oil feedstock in the presence of a catalyst wherein the yield of fuel product from the process is equivalent to or greater than the yield of fuel product resulting from running the process with no renewable fuel oil feedstock, on an energy input basis of the feedstock. In certain examples, the disclosure related to a method of preparing a fuel comprising processing a petroleum fraction feedstock with a renewable fuel oil feedstock in the presence of a catalyst wherein the fuel obtain from the process is completely compatible with fuel derived with no renewable fuel oil feedstock.

[0036]

[0037] In certain examples, the disclosure relates to a method of generating one or more cellulosic-renewable identification numbers comprising thermally processing a cellulosic biomass to form a renewable fuel oil (for example an unenriched renewable fuel oil) and co-processing a petroleum fraction feedstock with the renewable fuel oil in a refinery conversion unit to thereby produce a cellulosic-renewable identification number-compliant diesel fuel, jet fuel, gasoline, or heating oil.

[0038] In certain examples, the disclosure relates to a combustible fuel for an internal combustion engine, derived from a petroleum fraction feedstock and less than 5 wt.% of a renewable fuel oil feedstock wherein the renewable fuel oil feedstock and the petroleum fraction feedstock are co-processed in the presence of an FCC catalyst.

[0039] In certain examples, the disclosure relates to a method of improving an amount of valuable fuel components derived from the conversion of a petroleum fraction feedstock comprising introducing the petroleum fraction feedstock into a refinery system comprising an FCC catalyst and adding at least 2wt.% renewable fuel oil feedstock, relative to the total amount feedstock (for example petroleum fraction feedstock plus renewable fuel oil feedstock) and co-processing, in the presence of the FCC catalyst, the combined feedstock in the FCC for at least 2 seconds.

[0040] In certain examples, the disclosure relates to a method of trading renewable identification numbers, comprising co-processing petroleum fraction feedstock with a renewable fuel oil to form fuel compliant with one or more fuel pathways, in accordance with the U.S. renewable fuel standard program, and transferring the rights of at least a portion of the one or more U.S. renewable identification numbers from the owner or purchaser of the fuel. In certain examples, the disclosure relates to a renewable fuel oil compliant with a fuel pathway specified in U.S. renewable fuel standard program regulations for generating the cellulosic renewable identification number, derived by thermally processing cellulosic biomass. In certain

examples, the disclosure relates to an internal combustion engine fuel derived from a renewable fuel oil compliant with a fuel pathway specified in U.S. renewable fuel standard program regulations for generating the cellulosic renewable identification number. . In certain examples, the disclosure relates to an internal combustion engine fuel derived from a refinery conversion unit feedstock comprising 1-5 wt% of a renewable fuel oil compliant with a fuel pathway specified in U.S. renewable fuel standard program regulations for generating the cellulosic renewable identification number.

[0041] In certain examples, the disclosure relates to a blended combustible fuel composition comprising a FCC co-processed gas oil and renewable fuel oil product.

[0042] In certain examples, the disclosure relates to a method of using one or more of the above fuels in a vehicle comprising an internal combustion engine.

[0043] In certain examples, the disclosure relates to a computer system comprising monitoring an amount of throughput in an FCC unit and controlling the amount of renewable fuel oil to introduce for co-processing with petroleum based feedstock.

[0044] In certain examples, the disclosure relates to a computer system comprising monitoring an amount of throughput in an FCC unit inclusive of the quantity of renewable fuel oil being processed and calculating the cellulosic-renewable identification numbers generated.

DETAILED DESCRIPTION OF THE DRAWINGS

[0045] Many of the benefits of the materials, systems, methods, products, uses, and applications among others may be readily appreciated and understood from consideration of the description and details provided in this application inclusive of the accompanying drawings and abstract, wherein:

[0046] Figure 1: illustrates a fluid catalytic cracking (FCC) unit.

[0047] Figure 2A: illustrates a exemplary converter.

[0048] Figure 2B: illustrates a exemplary converter that has been retro-fitted with an injection port or two (102), with two different locations (which may be alternative locations or both used) suitable for introducing a renewable fuel oil (RFO) feedstock.

[0049] Figure 3: illustrates a riser quench technology.

[0050] Figure 4: illustrates a coking unit.

[0051] Figure 5: illustrates a feed injection system.

[0052] Figure 6: illustrates a FCC unit with dual risers.

[0053] Figure 7: is a graph presenting the influence of catalyst:oil ratio and RFO concentration in VGO on conversion (on a mass basis).

[0054] Figure 8: is a graph presenting the influence of catalyst:oil ratio and RFO concentration in VGO on overall conversion (on an equivalent energy input basis).

What is claimed is:

1. A method of preparing a fuel comprising

co-processing in a fluidized catalytic cracking unit (FCC) a petroleum fraction feedstock with a renewable fuel oil feedstock in the presence of a catalyst,
wherein the renewable fuel oil is an unenriched renewable fuel oil formed from ground-up biomass by a rapid thermal processing,
wherein the unenriched renewable fuel oil does not undergo any further pre- or postprocessing including no hydrodeoxygenation, no hydrotreating, no catalytic exposure or contact,
wherein the renewable fuel oil includes all of the whole liquid produced from the thermomechanical conversion of the biomass,
wherein the unenriched renewable fuel oil is used in an amount of less than 6 wt.%, less than about 5 wt.% or less than about 3 wt.% relative to the total weight of feedstock fed, and
wherein the petroleum fraction feedstock comprising a gas oil (GO) feedstock, a vacuum gas oil (VGO) feedstock, or a heavy gas oil (HGO) feedstock.

2. The method of claim 1, wherein the renewable fuel oil is a liquid formed from ground-up biomass by rapid thermal processing, wherein the resulting liquid is at least 60 wt.%, at least 70 wt.%, at least 75 wt.%, at 80 wt.% or at least 85 wt.% of the total weight of the processed biomass.

3. The method of claim 2, wherein the resulting liquid is at least 70 wt.%, at least 75 wt.%, at 80 wt.% or at least 85 wt.% of the total weight of the processed biomass.

4. The method of claim 1, wherein the renewable fuel oil has a pH in the range of 0.5 to 8.

5. The method of claim 1, wherein the renewable fuel oil has a solids content of less than 5 wt.%.

6. The method of claim 1, wherein the biomass comprises wood, wood residues, sawdust, slash bark, thinnings, forest cullings, bagasse, corn fiber, corn stover, empty fruit bunches (EFB), fronds, palm fronds, flax, straw, low-ash straw, energy crops, palm oil, non-food-based biomass materials, crop residue, slash, pre-commercial thinnings and tree residue, annual covercrops, switch grass, miscanthus, cellulosic containing components, cellulosic components of separated yard waste, cellulosic components of separated food waste, cellulosic components of separated municipal solid waste (MSW), or combinations thereof.

7. The method of claim 6, wherein the biomass comprises slash bark, thinnings, bagasse, corn fiber, corn stover, empty fruit bunches (EFB), fronds, palm fronds, flax, straw, low-ash straw,

energy crops, palm oil, non-foodbased biomass materials, crop residue, slash, pre-commercial thinnings, annual covercrops, switch grass, miscanthus, cellulosic containing components, cellulosic components of separated yard waste, cellulosic components of separated food waste, cellulosic components of separated municipal solid waste (MSW), or combinations thereof.

8. The method of claim 6, wherein the biomass comprises slash bark, thinnings, empty fruit bunches (EFB), fronds, palm fronds, flax, palm oil, non-food-based biomass materials, crop residue, slash, pre-commercial thinnings, annual covercrops, switch grass, miscanthus, cellulosic containing components, cellulosic components of separated yard waste, cellulosic components of separated food waste, cellulosic components of separated municipal solid waste (MSW), or combinations thereof.

9. The method of claim 1, wherein the petroleum fraction feedstock and the renewable fuel oil feedstock are introduced into the FCC unit through one or more independent or separate injection nozzles.

10. The method of claim 1, wherein the mix-zone temperature in the FCC unit is increased by injecting between 0.05 to 15 wt.% renewable fuel oil feedstock via a quench riser system downstream of the introduction of a petroleum fraction feedstock injection nozzle.

11. The method of claim 1, wherein the unenriched renewable fuel oil has a temperature not exceeding 65.5 °C (150 °F) on its way to being introduced into the FCC unit.

12. The method of claim 1, wherein the amount of renewable fuel oil is in the range of greater than 1% by weight and less than 5% by weight.