CLAIMS

What is claimed is:

1. A method of producing a fuel additive, comprising:

producing a first product stream comprising butadiene by passing a feed stream comprising C4 hydrocarbons including isobutylene, butadiene, 1-butene, 2-butene , cis-2-butene, trans-2-butene, or a combination thereof, through a steam cracker;

transforming greater than or equal to 90 weight % of the butadiene in the first product stream into a second product stream by passing the first product stream through a first hydrogenation unit comprising multiple reactors in series, wherein the second product stream comprises 1-butene, 2-butene, n-butane, isobutylene, isobutane, or a combination thereof and less than or equal to 5% by weight butadiene; and

converting the second product stream into the fuel additive by passing the second product stream through a fuel additive synthesis unit with an acid catalyst.

2. The method of Claim 1, wherein the feed stream comprises a portion of an effluent from a fluid catalytic cracking process.

3. The method of any of the preceding claims, wherein the feed stream further comprises methyl acetylene, propylene, 1, propene, isobutane, n-butane, or a combination thereof.

4. The method of any of the preceding claims, wherein greater than or equal to 95 weight %, preferably greater than or equal to 96 weight %, of the butadiene in the first product stream is transformed into the second product stream.

5. The method of any of the preceding claims, wherein the acid catalyst comprises phosphoric acid, sulfonic acid, sulfuric acid, nitric acid, hypophosphorous acid, metal oxide, zeolite, or a combination thereof.

6. The method of Claim 5, wherein the acid catalyst comprises a sulfonic acid resin, sulfonated polystyrene, hypophosphorous acid, supported niobium oxide, zeolite supported acid catalyst, or a combination thereof.

7. The method of any of the preceding claims, wherein the second product stream is converted into the fuel additive at a temperature of 25°C to 300°C, preferably 30°C to 250°C, more preferably 140°C to 200°C.

8. The method of any of the preceding claims, wherein the second product stream is converted into a fuel additive at a pressure of 0.25 MegaPascal to 20 MegaPascal, preferably 0.5 MegaPascals to 10 MegaPascals, more preferably 5 MegaPascal to 10 MegaPascal.

9. The method of any of the preceding claims, further comprising passing a water stream through the fuel additive synthesis unit.

10. The method of Claim 9, wherein a molar ratio of water to butene fed to the fuel additive synthesis unit is 0.5 to 25, preferably 1 to 20.

11. The method of any of the preceding claims, further comprising withdrawing a by-product stream from the fuel additive synthesis unit and passing the by-product stream through a second hydrogenation unit.

12. The method of Claim 11, wherein the by-product stream comprises 1-butene, 2-butene, isobutane, n-butane, or a combination thereof.

13. The method of Claim 11 or Claim 12, further comprising withdrawing a recycle stream from the second hydrogenation unit, wherein the recycle stream comprises n-butane, isobutane, or a combination thereof, and recycling the recycle stream back to the feed stream.

14. The method of Claim 13, further comprising passing the recycle stream through the steam cracker to produce propylene, ethylene, or a combination thereof.

15. The method of any of the preceding claims, wherein the first hydrogenation unit and/or the second hydrogenation unit comprises an oscillating baffle reactor, a fixed bed reactor, a fluidized bed reactor, a membrane integrated reactor, or a combination thereof.

16. The method of any of the preceding claims, wherein the fuel additive synthesis unit comprises an oscillating baffle reactor, a fixed bed reactor, multitubular reactor, a membrane integrated reactor, a reactive distillation unit, or a combination thereof.

17. The method of any of the preceding claims, further comprising:
withdrawing a fuel additive from the fuel additive synthesis unit; and
confirming the fuel additive comprises 2-butanol, tert-butyl alcohol, C4 dimer, or a combination thereof, preferably wherein the C4 dimer comprises di-isobutylene, 2,2,4-trimethylpentane, 2,3,3-trimethylpentane, or a combination thereof.

18. The method of any of the preceding claims, further comprising:
confirming the fuel additive comprises trimethylpentane in an amount greater than or equal to 0.01 weight %, preferably greater than or equal to 0.02 weight %, more preferably greater than or equal to 0.1 weight %, based on the total weight of the fuel additive.

19. The method of any of the preceding claims, further comprising:
a determining Research Octane Number of the fuel additive to be greater than or equal to 85, preferably greater than or equal to 86.

20. The method of any of the preceding claims, further comprising:
measuring a Reid vapor pressure of the fuel additive which is less than or equal to 55 Kilopascals, preferably 8 Kilopascals to 53 Kilopascals, more preferably 10 Kilopascals to 51 Kilopascals.