Renewable Diesel & Supercritical Biodiesel vs. Petro-Diesel

From A Biofuel Producer's Perspective, This White Paper Details The Relationship Between Legacy D975 Diesel Fuel, Renewable Hydrocarbon Diesel And Supercritical Biodiesel

JatroRenewables®

SUSTAINABLE CHEMISTRY FOR EARTH

12/14/17

Contents

Note: 1. MMgy = Million gallons per year. Maximum production capacity. Also called Nameplate.

What Is Renewable Hydrocarbon Diesel or Drop-In Diesel?

- Renewable hydrocarbon diesel (RHD), or simply Drop-In Diesel, is diesel fuel hydrotreated from biomass oils and animal fats
- RHD uses same feedstocks as biodiesel, but has different fuel properties
- Emits 80% less emissions than ULSD[1] with almost zero NOx
- RHD can be used neat and blended with petro-diesel (#2 ULSD)
- Engine warranties same as ULSD
- Logistics exactly the same as for ULSD - from Producer to Storage to Retail Pumps including Pipelines (Biodiesel and Ethanol can NOT use pipeline
- City fleets using RHD include: Oakland, San Diego, San Francisco and LA among many municip-alities in California

City of Oakland, CA motor pool, employee pumping RHD

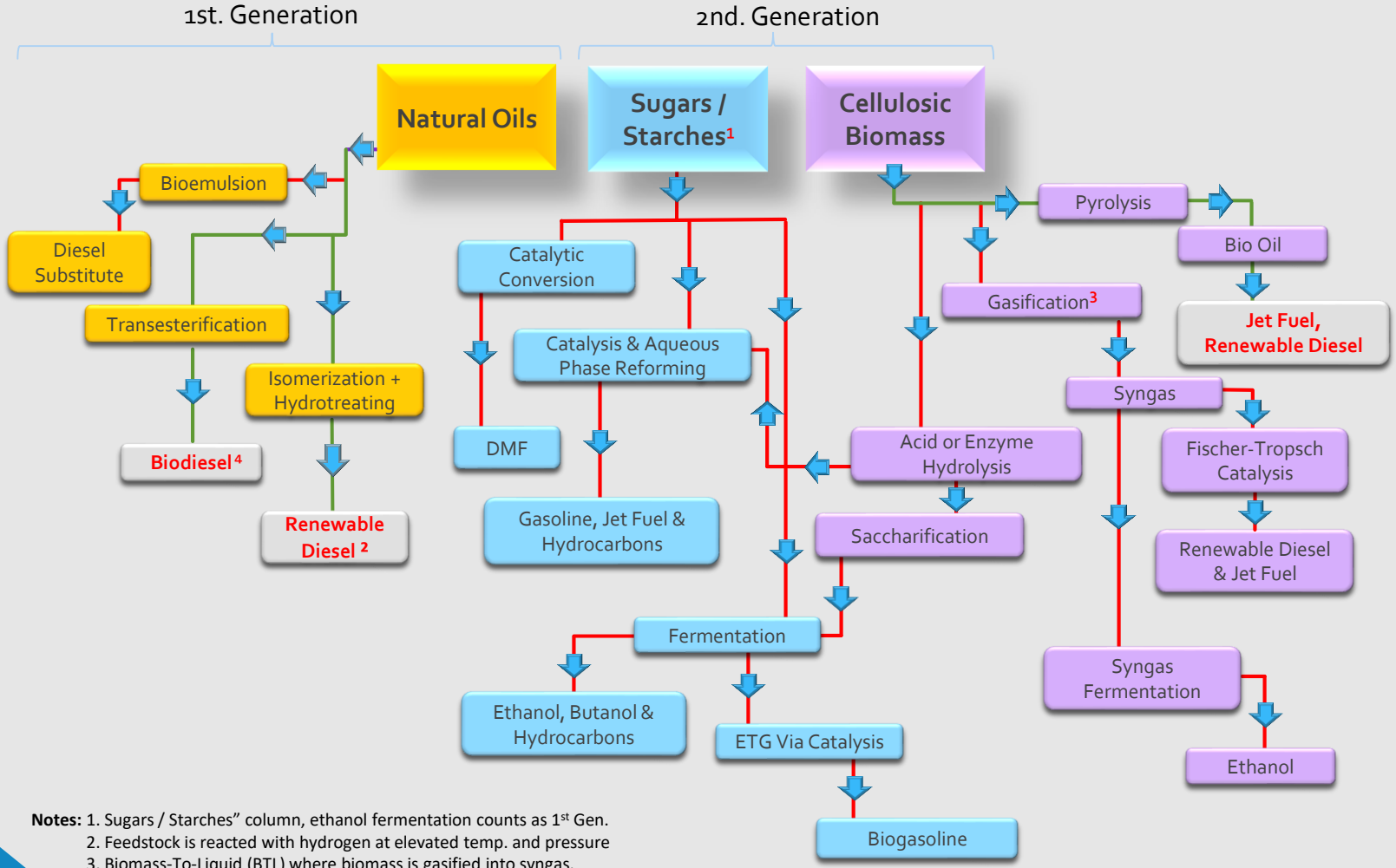
Notes: 1. ULSD = Ultra Low Sulfur Diesel (or #2 Diesel Fuel with <15 ppm sulfur).

1st Generation Renewable Fuels

Fuel Type	Fuel Standard: (U.S., CAN., & EU)	Feedstock	Refining Process	Usage Form
#2 Diesel (ULSD)	• U.S. ASTM D975 • CAN/CGSB 3.517 • EU, EN 15940	• Petro distillate rich in paraffinic hydrocarbons from crude oil	• Fractional distillation between 500C and 520C • At atmospheric	• 100%
Biodiesel (methyl ester)	• U.S. ASTM D6751 • CAN/CGSB 3.20 • EU, EN 14214	• Derived from biomass: Soy, Canola/Rapeseed, Sunflower etc. 40% usage • Animal fats, used cooking oil, trap grease represent 60% of usage	• Traditional: Transesterification & esterification w/catalyst • Jatro Renewables *Supercritical*: Trans-esterification w/o catalyst • Enzymatic hydrolysis	• To 80% with petrodiesel[1] but typically blended to ~20% with petrodiesel[2]
Renewable Drop-In Diesel (or RHD[4])	• U.S. ASTM D975 • CAN/CGSB 3.20 • EU, EN 15940	• Derived from biomass (seed oils & animal fats)	• Hydrotreating (similar to how crude oil is refined into #2 ULSD diesel fuel)	• 100%[3] (or blended any ratio w/diesel)

Notes: 1. To meet U.S. EPA Renewable Fuel Standard, must be below 80% biodiesel to ULSD
2. Canada has no blend limit, but usually <20% biodiesel to petrodiesel
3. 2% petrodiesel must be blended in under RFS and California LCFS rules
4. RHD = Renewable Hydrocarbon Diesel used inter-changeably with Renewable "Drop-In" Diesel

Fuel Technology Pathways



Notes: 1. Sugars / Starches" column, ethanol fermentation counts as 1st Gen.
2. Feedstock is reacted with hydrogen at elevated temp. and pressure
3. Biomass-To-Liquid (BTL) where biomass is gasified into syngas, cleaned then passed over solid metal catalyst
4. Gray boxes: Jatro Renewables pathways (products)

Features of Biodiesel and ULSD

Properties	Traditional Biodiesel (FAME)	Supercritical Biodiesel (*Super*™) ASTM 6751	Renewable Hydrocarbon Diesel ASTM D975
GHG Emissions	60% below baseline[1]	60% below baseline[1]	80% below baseline[1]
CAPEX / OPEX (15mmgy)	$1.36 | $0.67	$1.58 | $47	$1.95[2] | $0.57
Transportation	Truck, rail or barge	Truck, rail or barge	Plus pipeline
Storage	All tanks, above ground	All tanks, above ground	Same as UL:SD
Engine Compatibility	< 20% BD to meet manuf. warranty	< 20% BD to meet manuf. warranty	Same as ULSD
Cetane	About 47 to 51	About 47 to 51	70 to 94
Winter (Cloud Point)	Depending on feedstock blend -2°C to +8°C	Depending on feedstock blend -2°C to +8°C	Not dependent on feedstock blend: Low cloud point of -15°C. Can be adjusted to -40°C
Distribution	Max blend to <80% biodiesel, typically 2% to 20%	Must be blended to <80% biodiesel, typically 2% to 20%	No blending required
Fuel Color	Light yellow/ or light red	Clear (like water)	Clear (like water)
Retail Infrastructure	Separate pumps, tanks if 100%	Separate pumps, tanks if 100%	No changes

Note 1: The baseline is for #2 ULSD diesel fuel
2: Assumes taking hydrogen from the pipeline or stranded at a manufacturing facility. If hydrogen is manufactured from natural gas on site (with a Steam Methane Reformer) about a 50% to 75% capex increase

Fuel Properties Comparison

Properties	Petrodiesel	Biodiesel (*Super*™)	RHD
Cetane	40-50	47-65	70-94
Energy Density, MJ/kg	43	38	44
Density, g/ml	0.83-0.85	0.88	0.78
Energy Content, BTU/gal	129k	118k	123k
Sulfur	<10 ppm	<5 ppm	<10 ppm
NOx Emission	Baseline	+10	-10 to 0
Cloud Point, °C	-5	-2 to +5	-15 to -40
Oxidative Stability	Baseline	Fair	No limit
Cold Flow Properties	Baseline	Poor	Excellent
Lubricity	Baseline	Excellent	Good
Particulates	Baseline	33% lower	33% lower
NOx[1]	Baseline	5% higher	None
CO[1]	Baseline	20% lower	24% lower
Hydrocarbons[1]	Baseline	27% lower	30% lower

Fuel Effects on Vehicle Operation

Properties	Petrodiesel	Biodiesel (FAME)	RHD
Distillation Range	OK	OK (most not distilled)	Less lubrication degradation Change oil less
Cetane	Baseline	Good starting	Fast cold starts Lower tailpipe pollution Less engine noise
Oxidation Stability	Baseline	< 3 hrs w/o additive (test) 6 month shelf life	No oxygen = no limit Cleaner fuel system Less injector fouling
Cloud Point, °C	-5	-2 to +5 (Poor) Typically not used neat	-15 to -40
Oxidative Stability	Baseline	Fair	No limit
Cold Flow Properties, °C	To -40 w/additive	To -20 w/additive	Refined to -40
Ash	Miniscule amt.	< 0.005% by vol.	Almost zero. Excellent catalyst performance Extended particulate filter life
Chemical Composition	Hydrocarbon	Methyl ester	Hydrocarbon Extended oil life Less engine oil thickening
Solubility of Water	Low	Medium	Very low risk of water pick-up in logistics including storage

Continued . . .

Fuel Effects on Vehicle Operation

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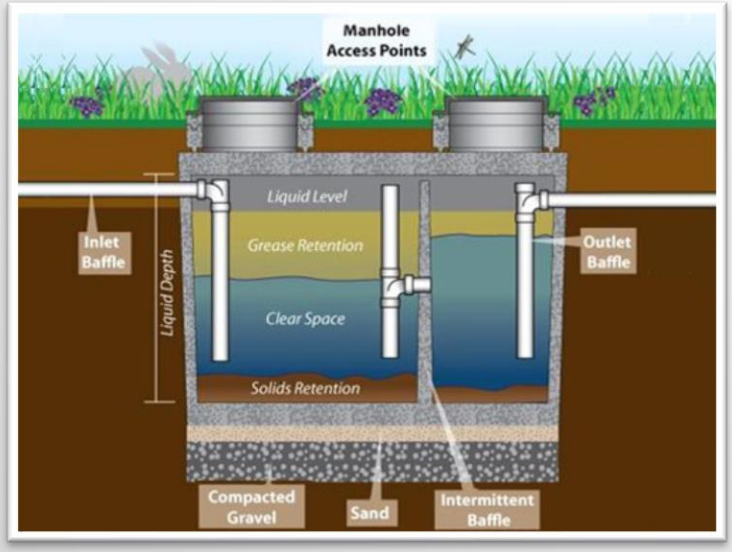
Properties	Petrodiesel	Biodiesel (FAME)	RHD
Fuel Consumption	Baseline	Same as baseline	2% to 4% higher than Petrodiesel 3% to 5% lower vs. neat FAME
Engine Power	Baseline	The same	The same except in older engines due to lower heating value of RHD
Engine Oil Dilution and Deterioration	Baseline	Due to higher boiling temps in distillation, slight chance fuel could contaminate engine	About the same as baseline
Injector Fouling	Baseline	(Typically not used neat) and would follow additive prescription for petrodiesel	Use typical detergents as petrodiesel especially for corrosion issues
Auxiliary Heaters	Baseline	Heaters as per petrodiesel requirement for up to ~20% biodiesel blends.	No cold weather issues, but if heater used, follow same regimen as petrodiesel
Optimizing Engines for RHD	Baseline	Optimization minimal	With advanced fuel injection timing, fuel consumption can be lowered 5% to 8%. by weight. Also, with retarded timing, NOx can be reduced but decreases fuel economy; however, by optimizing the Emissions Gas Recirculation unit will mitigate that issue.

Lower Cost Feedstocks for the Supercritical and RHD Processes

Jatro Renewable biodiesel and RHD processing technologies fulfill important changes by providing Producers access to lower cost feedstock without compromising the quality of the finished biodiesel or RHD



- *Cost to a biodiesel producer for trap grease is less than half that of typically used feedstocks such as yellow grease, used cooking oil and corn oil. Municipalities across the U.S. contract with approved vendors to pick up the grease.*

- *Other low cost feedstocks are derivatives of Palm Oil where some have very high FFAs and available in large quantities. The U.S. and Europe don't allow biodiesel to be made from anything in the palm family due to deforestation for palm planting. However, some types are under review by the EPA. Also, EPA is considering Whey, a by-product of Yogurt drinks processing.*

Margin Comparison – 50mmgy

Criteria	Traditional BD	Supercritical BIODIESEL	RHD (California)
Production/Year (gals)	50,000,000	50,000,000	50,000,000
CAPEX	$47,000,000	$53,000,000	126,500,000
Cost Per Nameplate Gal.	$0.94	$1.06	$2.53
Feedstock/lb (dlvd)	$0.28	0.26[2]	0.30[2]
Feedstock/gal	$2.10	1.89	2.26
Operations (freight in/out)	$0.79	0.59	0.64
Total Cost	$2.89	2.48	2.90
Revenue B100 (dlvd.)	$3.20	3.25	3.50[4]
By-Products (fob)	$0.04	0.09	0.06
Total Revenue/gal[3]	$3.24	3.24	3.81
EBITDA/gal	$0.35	0.76	0.91
Total EBITDA/Year	$17,500,000	38,000,000	45,500,000
Months to Payback	36	17	31
IRR (10 years)	29%	63%	31%

Notes: 1. Includes all plant equipment, tanks, permitting and labor, system uses SMR. Deduct capex of about $20m to $30m if connecting to H2 pipeline.
2. About 25% low cost feedstock blend (corn oil and YG/UCO @ $0.29 dlvd; brown grease $0.14 dlvd)
3. Based USDA and TheJacobsen spot index pricing 03/12/18
4. Higher margin due to LCFS in California. Assmues Traditional snd Super operate outside the state.

Margin Comparison – 15mmgy

Criteria	Traditional BD	Supercritical BIODIESEL	RHD (California)
Production/Year (gals)	15,000,000	15,000,000	15,000,000
CAPEX	$21,200,000	$23,700,000	37,500,000[1]
Cost Per Nameplate Gal.	$1.41	$1.58	$2.50
Feedstock/lb (dlvd)	$0.28	0.26[2]	0.30[2]
Feedstock/gal	$2.10	1.89	1.89
Operations	$0.79	0.59	0.64
Total Cost	$2.89	2.48	2.53
Revenue B100 (dlvd)	$3.20	3.25	3.60
By-Products (fob)	$0.04	0.09	0.06
Total Revenue/gal[3]	$3.24	3.34	3.66
EBITDA/gal	$0.35	0.86	1.13
Total EBITDA/Year	$5,250,000	$12,900,000	16,950,000
Months to Payback	48	21	26
IRR (10 years)	18%	47%	32%

Notes: 1. Includes all plant equipment, tanks, permitting and labor, system uses SMR. Deduct about $12m if connecting to pipeline. Does not include civil nor building (if necessary)
2. Increased freight from U.S> to Calif. About 25% low cost for feedstock blend (corn oil and YG/UCO @ $0.29 dlvd; brown grease $0.14 dlvd)
3. Based USDA and TheJacobsen spot index pricing for Midwest 7/18/17

Diesel Fuel Subsidies For USA

Program	Subsidy Description	Value		
Renewable Fuel Standard (RFS)	Refiners (Obligated Parties) Required to Blend in X% (Renewable Volume Obligation) Into Diesel Fuel Pool. Each gallon is numbered and called a Renewable Identification Number (RIN) and designated by type of fuel (Biodiesel and RHD called D4)	If Refiner does not want to blend, can buy on the market a RIN from others that have proof (from their blending report to EPA).		
		For RHD: a D4 RIN x 1.7[1] = $1.83/gal. (As a "drop-in" fuel, no blending required. Producer may retain the RIN to transact) For Biodiesel a D4 RIN x 1.5[1] = $1.62/gal. (Blender must blend then transact RIN)		
IRS Producer Credit	Technically a subsidy, (no taxes need be owed). Currently program suspended until Congress acts to extend. Expected to eliminate imported biodiesel and RHD and extended 3 years retroactive for 2017	$1.00/gallon (plus $0.10 for small producers at <15mmgy)		
Calif. Low Carbon Fuel Standard (LCFS)	Program requires all biodiesel and RHD meet certain carbon intensity (CI) values determined by total carbon inputs from well to wheel and by type of feedsotck used. A computation of CI to the market value of the LCFS credit determines the value of a credit per gallon of fuel.	CI Value (Examples)	LCFS Credit Per Ton	Credit Value[2] Per Gallon
		83 (soy) 53 (soy &YG) 28 (Tallow) 12 (UCO)	$95	$0.18 0.64 0.84 1.04
Oregon	Same as California but retains its own market value for LCFS credit/ton	80 (soy)	$55	$0.10
Washington	To start in 2018			

Notes: 1. RHD has a higher BTU (energy) content than biodiesel
2. Requires a GREET-2.0 calculator to determine value per gallon

Diesel Fuel Mandates For Canada

Province	Ethanol Mandate for Gasoline	RHD Mandate for Diesel
British Columbia	5%	4%
Alberta	5%	2%
Saskatchewan	7.5%	2%
Manitoba	8.5%	2%
Ontario	5%	2% to 4%[1]
Quebec	5% (inspirational mandate)	None

Notes: 1. Depends on GHG reduction

About Jatro Renewables

- **PROJECTS**
  14 years Engineering and Constructing Process Systems for the Chemical Processing Industry – 19 Projects in the Renewable Fuels Industry

- **TECHNOLOGIES**
  Licensed, Patented Processes include
  Supercritical Biodiesel,
  Renewable Hydrocarbon Diesel
  Re-Refining of Used Oils

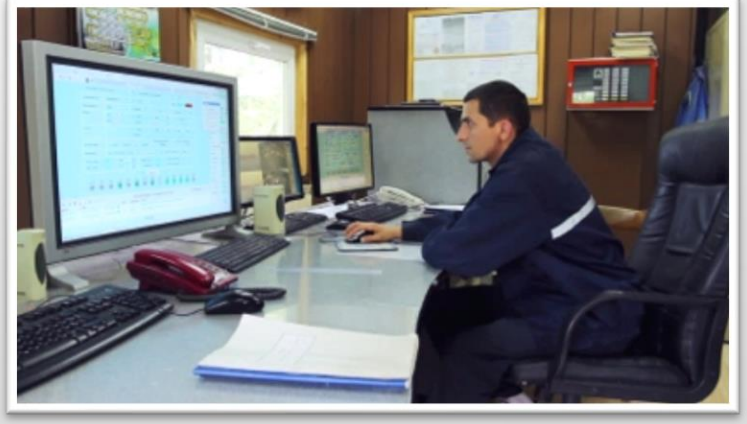
- **SERVICES**
  Mass Transfer Design & Engineering for Modular Processes. In-house Pilot Testing, Skid Mounted Systems, Plant Construction, Training, Start-up and Optimization Leading to Commercialization

Supercritical system at CHS, Inc., Illinois

Renewable Fuels Our Specialty

- Jatro Renewables founded in 2004 with partners
- Built first biodiesel plant near Dayton, OH
- 2006 began installing biodiesel plants and mass transfer modular systems in the U.S.
- 2010 adapted "*esterification*" to allow use of lower cost oils (to 15% FFA from 3% FFA)
- By 2012 the company developed a patented technology called "*Supercritical*" to process oils with up to 100% FFA
- Supercritical process lowers opex by 35%
- 19 plants installed since 2004
- 1 plant using Supercritical, another under construction (in 2017 company awarded grant from California Energy Commission for $3.8m)
- In 2015 company began offering a wider range of engineering services to the chemical industry
- In 2017 company began offering patented Renewable Hydrocarbon Diesel ASTM D975 with one commercial system and another (formerly operating) moved to another location (and currently under construction.

Esterification system at Vanguard Biodiesel, Louisiana



Design and engineering services including detailed 3D renderings

Other Services

Distillation Technology
Solvent Recovery Systems
Batch and Continuous
Extractive Distillation
Reactive Distillation
Pressure Swing Distillation

Liquid-to-Liquid Extraction
Packed Columns
Agitated Packed Columns
Agitated Tray Columns

Fats & Oleochemical
Dry Fractionation
Fat Splitting
Fatty Acid Fractionation
Glycerin Purification
Hydrogenation

Edible Oil Refining
Degumming
Bleaching
Deodorizing
Heat Exchangers

Process Equipment
Columns
Heat Exchangers
Reactors
Vessels etc.

R&D Set-up (Skids)
Pilot Trials
Semi Production Scale
Skid Mounted Pilot

Evaporation
Falling Film
Forced Circulation
Agitated Thin Film
Multiple Effect Evaporators

Processes for Oil & Gas
TEG Dehydrators
Amine Sweeteners
Used Oil Refining
White Spirit Plant
Crude Oil Refining
Vacuum Distillation Unit
Condensate Fractionate Unit
Process Packages for Oil & Gas

Jatro Renewables maintain on-site oversight of all work in progress

Environmental Technology
Supercritical Biodiesel
Renewable Hydrocarbon Diesel
Bio Methanation - Biogas Production
Direct Oxidation Systems
Catalytic Oxidation Systems
Condensation Oxidation Systems
Active Carbon Absorption
VOC & Odor Removal

Engineering Services
Detailed Engineering Designs
State-Of-The-Art Processes (including 3D).

Design & Fabrication

We are an integrated engineering and manufacturing company serving the chemical mass transfer processing industry

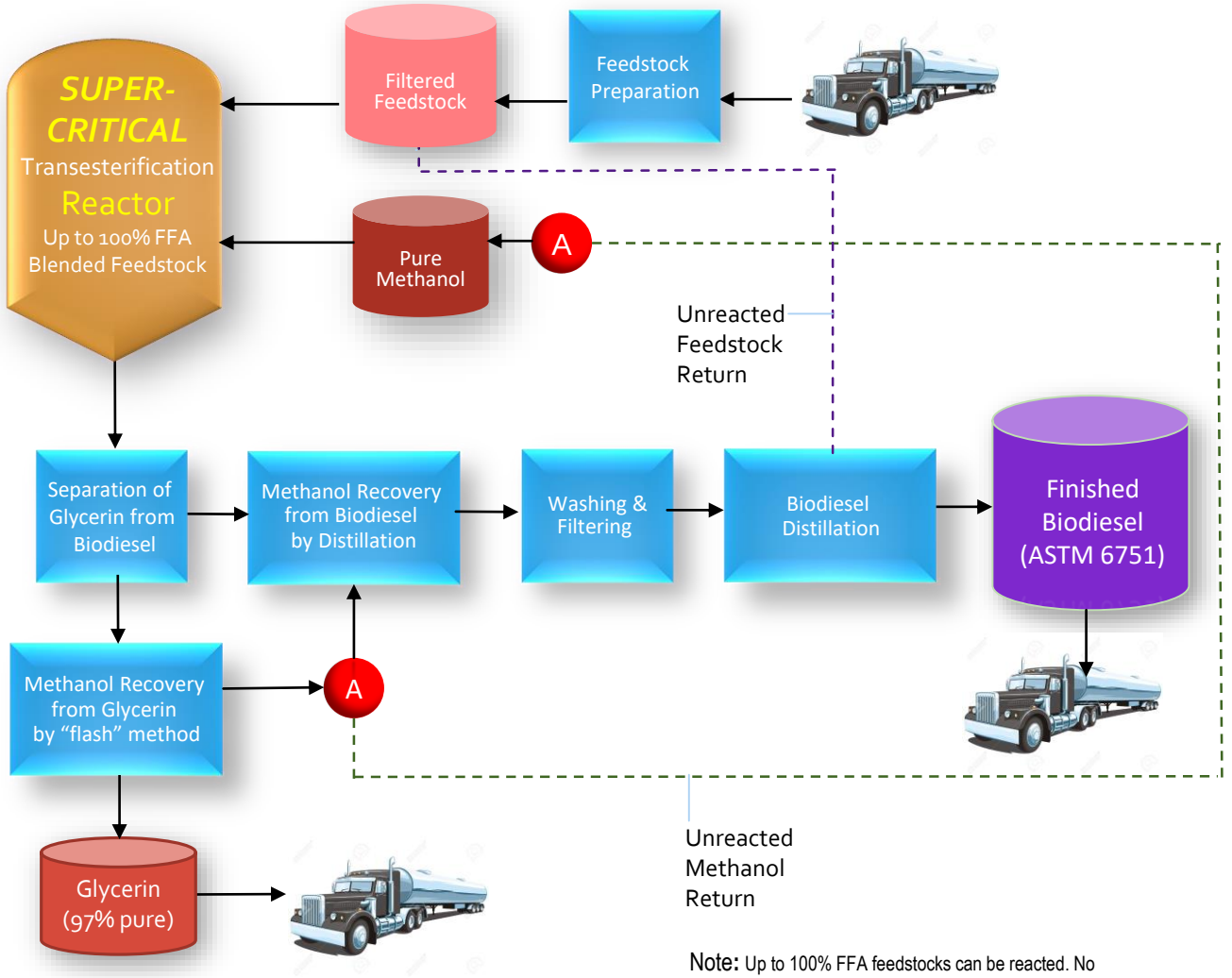
Jatro Renewables maintains direct supervision over components in manufacturing to insure exactness and quality

Jatro Renewables manages its manufacturing shops both in the U.S. and India for most of the components the company engineers and builds

APPENDIX

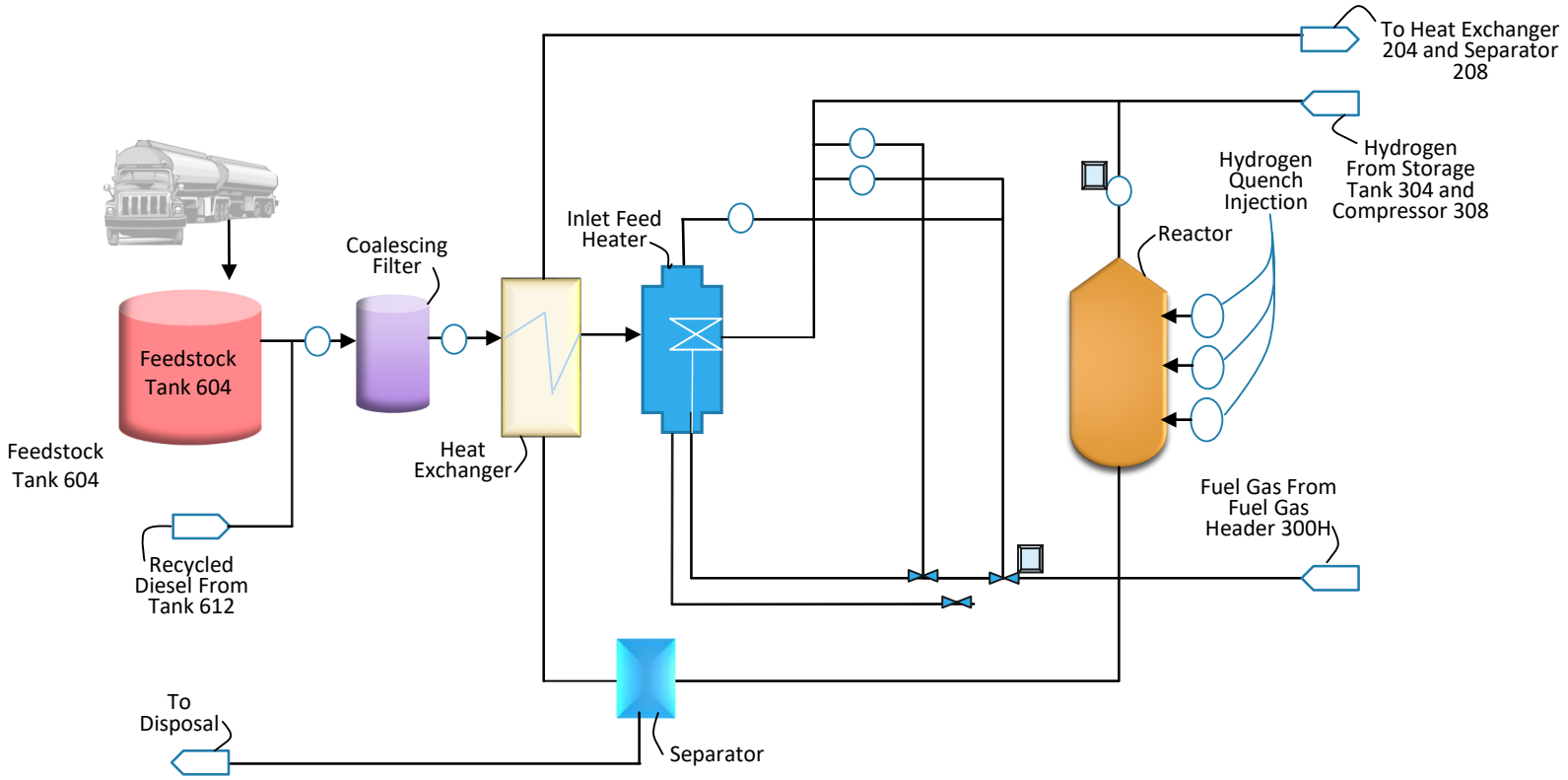
The following pages diagrams are patented processes for refining virgin oil, animal fats and other similar oils into Biodiesel (ASTM 6751) and Renewable Hydrocarbon Diesel (ASTM D975).

Supercritical Biodiesel Process



Note: Up to 100% FFA feedstocks can be reacted. No catalyst is used. With biodiesel distillation product comes out clear (no color).

Renewable Hydro. Diesel Process[1]



Note 1: Partial schematic

Renewable Diesel Process[1]

Feedstock filtered to remove water and particulates

Heat feedstock for Reactor treatment

Mix heated feedstock with Hydrogen

Treat feedstock and hydrogen mixture in Reactor using hydrotreating catalyst

Cool product from the Reactor

Separate vapors from liquids in separator

Distill product in the distillation column

Remove RHD from distillation and store for distribution

By-Products:
- Naphtha LPG
- LPG Vapor,
- Purge Gas

RHD Finished Product Tank