Method 2B Application: Renewable Diesel & Gasoline Pathways Life-Cycle Analysis Report

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Confidential Business Information Removed

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Summary

Terminology

Terminology associated with the aforementioned process, and used throughout this document include:

- **CA-GREET 2.0, GREET,** or **GREET 2.0** – refers to the CA-GREET 2.0 Excel model for estimating pathway energy use and emissions
- **Pyrolysis Gasoline** or **RG** or **RG100** – in the context of this report, refers to Renewable Gasoline produced according to the pathway described herein
- **Pyrolysis Diesel** or **RD** or **RD100** or **RDII 100** – in the context of this report, refers to Renewable Diesel produced according to the pathway described herein
- **RTP** – Rapid Thermal Processing, a proprietary fast thermal conversion technique featuring internal processing of co-products to minimize external energy requirements[1]
- **RFO** – Renewable Fuel Oil, or pyrolysis oil i.e. the product of the RTP process
- **WTT** – refers to Well-To-Tank emissions associated with a particular pathway; i.e. those emissions associated with production of the fuel up to, but not including combustion in a vehicle for motive power
- **TTW** – refers to Tank-To-Wheel emissions associated with combustion of a fuel in a vehicle
- **WTW** – refers to Well-To-Wheel emissions associated with a particular pathway; addition of **WTT** and **TTW**
- **VGO** – Vacuum Gas Oil, an intermediate refinery stream which is processed in a Fluid Catalytic Cracker Reactor to produce various end-products including gasoline and diesel
- **Tree Residues** – residues from processing planted trees of managed forests at lumber and paper mills, essentially sawdust, composed of woody biomass which meets RFS2 feedstock certification requirements
- **Forest Waste** or **Forest Residue** – may be used in some cases, for example when reflecting CA-GREET 2.0 labeling, to refer to tree residues, e.g. sawdust composed of woody biomass which meets RFS2 feedstock certification requirements
- **GWP** – Global Warming Potential (GHG conversion factor to equivalent mass of CO_2)

[1] For detailed information on the RTP process, please refer to Appendix A.

GREET Model Pathway for Tree Residue Renewable Gasoline and Diesel

GHG Model Summary

A Well-To-Tank (WTT) Life Cycle Analysis of a fuel (or blending component of fuel) pathway includes all steps from feedstock production to final finished product. Tank-To-Wheel (TTW) analysis includes actual combustion of fuel in a motor vehicle for motive power. Together WTT and TTW analysis are combined together to provide a total Well-To-Wheel (WTW) analysis.

The Life Cycle Analysis in this report was developed using the California-modified Greenhouse gases, Regulated Emissions, and Energy use in Transportation 2.0 model (CA-GREET 2.0, or GREET herein). The model was produced by CARB based on work by Argonne National Laboratory and released in June, 2015. The model has been used to calculate the WTT and WTW energy use and GHG emissions associated the production of renewable gasoline and diesel from tree residues using Ensyn's RTP technology. The decision to use CA-GREET 2.0 instead of 1.8b was based on the following factors:

- CA-GREET 2.0 includes a very relevant pyrolysis process (including refinery co-processing);
- CA-GREET 2.0 contained updated cellulosic biomass feedstock parameters and other emission factors, etc.;
- ARB staff feedback indicated that using CA-GREET 2.0 would facilitate review, revision and/or re-application under the re-adopted LCFS, as/if necessary.

Pathway Summary

This document provides a comprehensive inventory of the energy and inputs required to produce renewable gasoline and renewable diesel from tree residues for Ensyn's Refinery Coprocessing pathway. This application is being jointly filed by Ensyn Corporation, Tesoro Corporation and Chevron Corporation. The Refinery Coprocessing pathway is vastly different than existing downstream biofuel pathways. Under Refinery Coprocessing, biofuel is delivered upstream of the refinery, displaces crude oil in the refinery, and is subsequently refined into renewable gasoline and diesel alongside conventional fuels. The resulting renewable gasoline and diesel products meet ASTM specifications and can be blended with ethanol and biodiesel, allowing for greater adoption of biofuels in excess of current ethanol and biodiesel blendwalls. Existing biofuel pathways simply blend finished biofuels with finished gasoline and diesel downstream of the refinery, and are currently limited by blendwall constraints. A full description of Ensyn's RTP biofuel technology and the Refinery Coprocessing pathway can be found in Appendix A.

The physical pathway includes tree residues collected in the area of Renfrew County, Ontario, Canada, processed into Renewable Fuel Oil (RFO) at an RTP facility in Renfrew, Ontario, and transported to a conventional refinery in California for coprocessing in a Fluid Catalytic Cracker into transportation fuels. The maximum transport distances pertaining to delivery of RFO to the five co-applicants' refineries were conservatively used in the carbon intensity calculations below. Three of these refineries are operated by Tesoro and identified herein as Carson, Wilmington and Martinez. The other two are operated by Chevron and are identified as El Segundo and Richmond. Both refining companies are supporting Ensyn in the development of this joint pathway application because they intend to purchase RFO for Coprocessing in their respective refineries.

In the context of the pathways documented herein, tree residues, which are residues from processing planted trees of managed forests at lumber and paper mills, is essentially sawdust, the woody debris generated during milling operations. The residues used in this process qualifies as certified RFS2 feedstock and requires no additional pre-processing before delivery to the RTP facility. Residue collection activities are limited to loading and transport to the RTP facility. A front end loader is used for loading. Although the tree residues may otherwise be loaded and transported for landfill disposal anyhow, the energy use associated with this activity has been included fully, instead of being limited to the incremental requirements relative to the baseline of landfill disposal.

This approach is conservative and proactively addresses the alternative of treating sawdust as a low-value product, since it can in some cases be sold to other wood products companies. Selling sawdust is a cost-recovery technique as it would account for only a tiny fraction of a mill's total output both in terms of mass and revenues[2]. Any upstream energy use and emissions from e.g. logging operations would therefore be de minimis once allocated on either basis.

Well-to-tank greenhouse gas emissions in this document have been calculated based on energy requirements, with one exception. The WTT include residue collection, transport to a Renewable Fuel Oil (RFO) production facility, RFO production, RFO transport to refinery facilities, RFO coprocessing in the refinery and, finally, transportation of finished gasoline and diesel to distribution centers (T&D). TTW includes the combustion of renewable gasoline and renewable diesel in motor vehicles for motive power. Due to the biogenic source of the finished fuels' carbon, the CA-GREET 2.0 default of 0 is employed.

Figure 1 below provides an outline of the discrete components that comprise the tree residues to renewable gasoline/diesel pathways, from residue collection to transport and distribution (WTT) including the Coprocessing of RFO at one of five conventional refineries.

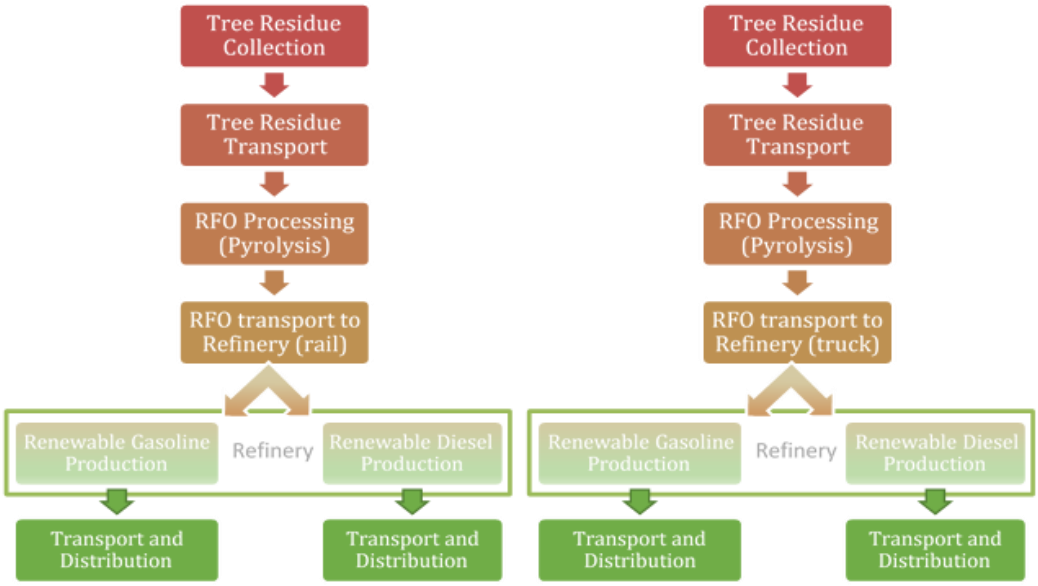

Figure 1 - Proposed Pathways

[2] Interview with resource forestry expert, May 14, 2015.

Renewable Gasoline Summary Results

RG Summary with RFO Transport by Rail

Item	Feedstock	Fuel	Vehicle Operation
VOC			
CO			
CO_2			
CH_4			
N_2O			
Total GHGs:			
		Total g CO_2e / MJ	20.12

RG Summary with RFO Transport by Truck

Item	Feedstock	Fuel	Vehicle Operation
VOC			
CO			
CO_2			
CH_4			
N_2O			
Total GHGs:			
		Total g CO_2e / MJ	25.03

Renewable Diesel Summary Results

RD Summary with RFO Transport by Rail

Item	Feedstock	Fuel	Vehicle Operation
VOC			
CO			
CO_2			
CH_4			
N_2O			
Total GHGs:			
		Total (g CO_2e / MJ)	21.67

RD Summary with RFO Transport by Truck

Item	Feedstock	Fuel	Vehicle Operation
VOC			
CO			
CO_2			
CH_4			
N_2O			
Total GHGs:			
		Total (g CO_2e / MJ)	26.58

Appendix G: Reference Documents

1. G1: Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: A Design Case
2. G2: Well-to-Wheels Analysis of Fast Pyrolysis Pathways with GREET
3. G3: Detailed California-Modified GREET Pathway for Cellulosic Ethanol from Forest Waste
4. G4: Real-world In-use Activity, Fuel Use, and Emissions for Non-road Construction Vehicles: A Case Study for Excavators
5. G5: National Renewable Energy Laboratory (NREL), Department of Energy Bioenergy Technologies Office (DOE BETO), Petrobas and Ensyn 2015 Project Peer Review: Petrobas-NREL CRADA

(Attached documents)