NESTE OIL

NExBTL® Renewable Diesel
Singapore Plant

USED COOKING OIL PATHWAY DESCRIPTION

1 INTRODUCTION

Neste Oil is the world's leading producer of Renewable Diesel with on-line capacity of 2 million metric tonnes per year (2 Mt/a) equivalent to 675 million gallons per annum distributed among its three world-wide facilities in Porvoo, Finland; Rotterdam, Holland and Singapore. Branded under the name of NExBTL®, this renewable diesel is a fully fungible, low-carbon, low-emission, paraffinic biofuel. Compared to petroleum diesel, NExBTL® has a higher cetane number and contains no aromatic compounds or sulphur. This translates into superior combustion properties compared to petroleum diesel.

This report outlines the NExBTL® Renewable Diesel production process as realized in the Neste Oil Singapore facility located at 1 Tuas South Lane, 637301 Singapore using used cooking oil feedstock procured from noodle production facilities in Asia. The NExBTL® Renewable Diesel refinery is built in the Tuas Industrial District, approx. 30 minutes from the centre of Singapore. The refinery is integrated into the area's existing industrial infrastructure, and makes use of local site utilities and port and storage services.

2 FEEDSTOCK ORIGIN AND SUPPLY

Feedstock considered in this pathway is used cooking oil (UCO) from food industry. Used cooking oil (UCO) is purchased from ***** CBI ***** in the Asian region, ***** CBI *****. The cooking oil is discarded after ***** CBI ***** and is collected as UCO.

The UCO undergoes a physical straining process via fine mesh fabric filtration prior to collection where little waste is generated and no yield factor is realized, but does not undergo any additional rendering. ***** CBI *****. Since UCO is considered to be a waste, the energy used and GHG emissions from its production are not included in this analysis.

The UCO is transported 100 miles by truck to ports and then shipped 1116 nautical miles to the Neste Oil NExBTL® Renewable Diesel (RD) Singapore plant. The UCO obtained from these facilities requires no rendering prior to being used in the Neste Oil Singapore plant. The UCO is used as feedstock in the NExBTL® Renewable Diesel process as described below. The final product is shipped by tanker to California.

This data was used to modify the CA-GREET model for the calculation of GHG emissions.

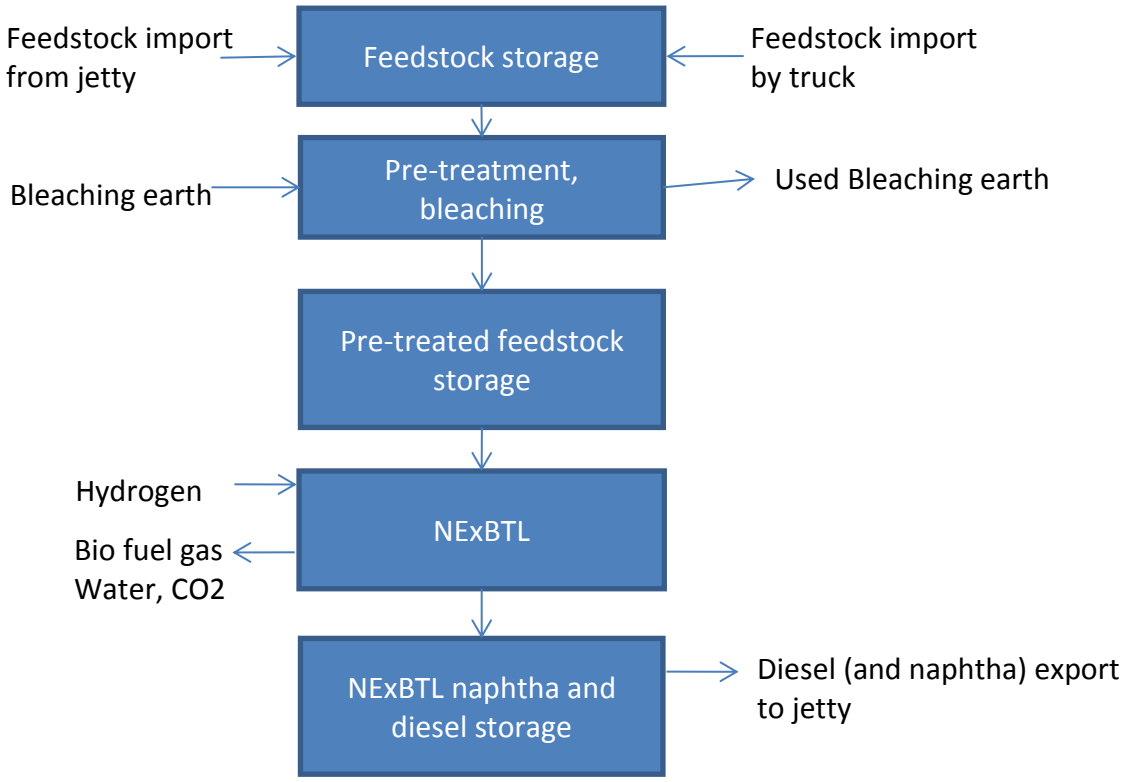
3 NExBTL® PROCESS OVERVIEW

The overall features of the Singapore NExBTL® Renewable Diesel production plant are shown in Figure 1. The process is comprised of a number of sub process units which are described in more detail below which are:

- Pre-treatment (impurities removal);
- Hydro treatment (oxygen removal, paraffins production and branching)
- Stabilization (removal of residual light gases);
- Recycle (hydrogen recovered & recycled; water, carbon dioxide removal, light gases recovered)

The propane off gas from the Recycle section is used in the steam methane reformer (SMR) plant for the production of hydrogen and the propane off gas from the Stabilization section is used in a natural gas boiler to raise process steam.

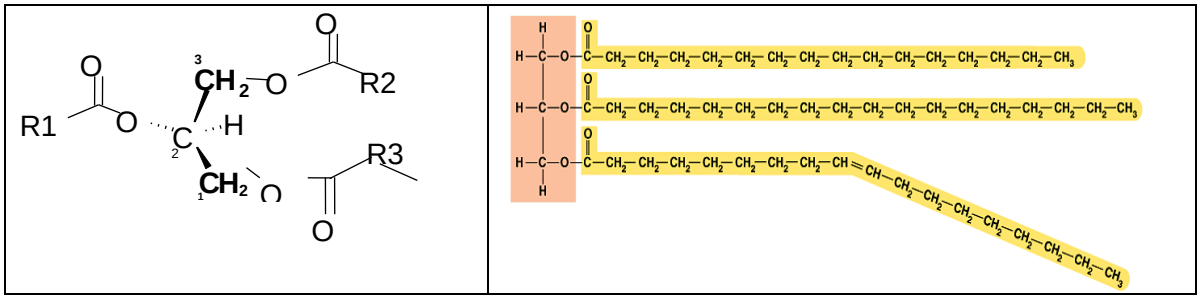
Figure 1 NExBTL® Singapore Process Diagram



4 MASS BALANCE (THEORETICAL)

The feedstocks for the process are vegetable oils and animal fats. NExBTL® Renewable Diesel plants are also able to process fatty acids. Common triglyceride representations are shown below. The side chains R1, R2, R3 vary by length and are typically in the range of C14 to C18.

Figure 2 Triglyceride molecule models



A simplified mass balance for a model triglyceride $C_{57}H_{102}O_6$ (molecular weight 882 g/mole) is presented. Oxygen is removed as both water (H_2O) and as carbon dioxide (CO_2). The ratio depends on the catalyst and particular conditions employed. A typical ratio is shown in the example below. The equation is written without the production of bio-naphtha as only very small volumes of light hydrocarbons are formed.

A simplified mass balance of the renewable diesel process can be written as:
1.18 kg $C_{57}H_{102}O_6$ + 0.035 kg H_2 →1 kg RD +0.05 kg CO_2 +0.1 kg H_2O +0.06 kg C_3H_8

Since there are impurities removed in the pre-treatment of purification stage which must be removed prior to processing, a slightly higher amount of feed is needed in practice than in the above equation.

5 DESIGN CAPACITY

The Singapore plant has a design capacity of approximately 114 tonnes / hour NExBTL® renewable diesel. Based on an annual operating hours of 8760 hours this translates into 832 000 tonnes / year.

6 REALIZED SINGAPORE MASS BALANCE

The Singapore plant was officially opened in March 2011. During the start-up period, the plant capacity was raised and individual process units thoroughly tested. The results of energy and mass balances during the start-up phase of a production plant are not relevant for use in GHG calculations as the plant was not operating in a steady state mode and the energy consumption and chemicals consumption are not representative of full capacity values.

A representative mass balance for the plant is shown in Table 1 below. Comparison of the realized mass balance to that calculated from reaction stoichiometry illustrates that the actual values are very similar to the calculated values. Combining the values of HP & LP off gases (containing bio propane) gives 0.06 t/t NExBTL®.

The carbon dioxide and water amounts are not reported in the table.

Table 1 Mass Balance NExBTL® Singapore

	t per t NExBTL®
Pretreatment Total Feed	1.21
NExBTL® Unit Feed	1.18
Hydrogen to NExBTL® Unit	0.038
NExBTL® Unit Production and Yields	
NExBTL® Product	1
Bio naphtha Product	0.0052
HP propane rich off gas	0.0505
LP propane rich off gas	0.0096

7 FEEDSTOCK PRE-TREATMENT SECTION

The function of the pre-treatment unit (PTU) is to reduce the level of impurities in the feed to acceptable levels and thus ensure a long catalyst lifetime.

The pre-treatment unit is designed for the continuously processing of vegetable oils and fats. The pre-treatment process is based on a bleaching unit (BLU). The bleaching unit can be operated independently from the rest of the plant and the operational configuration depends on the type and quality of the feedstock to be treated.

The bleaching process begins with the addition of an acid, forming a salt, and removal of the salt by precipitation. The resultant feedstock is then fed through silica and/or bleaching earth which act as adsorbents for further reduction of impurities. Spent bleaching earth is disposed off-site.

The levels of acids or bleaching earth used are typically in the range of 0.003 to 0.0003 kg /kg of NExBTL® Renewable Diesel.

8 HYDRO TREATING SECTION

8.1 Hydro deoxygenation (HDO)

The catalytic hydro treatment of triglycerides occurs through consecutive reactions forming three, straight chain paraffins; plus propane, water and carbon dioxide. There is 100% conversion of triglycerides in the reactor. This reaction step is normally referred to as hydro deoxygenation or HDO.

The reaction takes place by contacting the triglycerides with hydrogen over catalysts at elevated temperatures and pressures.

The HDO hydro treating reactions are exothermic. The excess heat is removed from the process and used to heat up the incoming feed reducing external energy use.

The gases produced during this step are fed to the Recycle section after water has been condensed out for recycle and reuse.

8.2 Isomerization

After the HDO step, the paraffins are branched or isomerized. Isomerization is used to improve the cold flow properties of the final fuel. The reaction is carried out in an atmosphere of hydrogen but there is negligible hydrogen consumption in this step

The liquid hydrocarbons are next fed to the diesel stabilization column.

9 HYDROGEN PRODUCTION SECTION

Hydrogen is produced off-site in a Steam Methane Reformer (SMR).The SMR plant is located on nearby Jurong Island and connected to the Neste Oil Singapore plant via a hydrogen pipeline network. Hydrogen consumption is typically 0.1 MJ / MJ NExBTL®.

Both natural gas and propane rich HP off gas are used in the SMR plant. The HP propane rich off gas is supplied in a dedicated pipeline. The natural gas used in the SMR plant is from the local natural gas network that is imported from Malaysia and Indonesia.

10 STABILIZATION SECTION

Product from the isomerisation reactor is routed to the stabilization column where light hydrocarbons are separated by stripping with low pressure steam. The stripping steam is generated in the waste heat boiler from condensate with heat of the diesel stabilization column bottom product. Hydrocarbons that are stripped are called LP off gas.

11 GAS SEPARATION AND RECYCLE SECTION

The function of this section is to separate the gas mixture into individual gas streams for use or removal and disposal. Hydrogen is returned to the process for use while the high pressure (HP) propane rich off gas is sent to a steam methane reformer (SMR) for hydrogen production and low pressure (LP) propane rich off gas is sent to a natural gas steam boiler for process steam production.

The gases are selectively and sequentially removed by first absorption or washing with an aqueous amine solution followed by amine regeneration where the individual gases are separated.

The recycle section is comprised of a number of wash columns and regeneration columns. The carbon dioxide and water streams are cleaned before releasing to the atmosphere or to the wastewater system.

Hydrogen is recovered by its selective permeation through a membrane. Hydrogen is then compressed and ready for use in the process.

12 CO-PRODUCT HP PROPANE OFF GAS CREDIT

In the recycle section of the Neste Oil Singapore plant, the biogenic propane rich HP off gas generated by the process displaces an energy equivalent of natural gas (NG) that would otherwise have been consumed as both process fuel and as feedstock in the SMR. In order to calculate the greenhouse gas savings due to this HP propane rich off gas stream, this may be modelled by first assuming a NG only consumption in the SMR that is without recycling of the off gas, and then subtracting a credit for the amount of NG displaced.

Based on the production figures for the Singapore plant during the time period in question, the propane rich HP off gas displaces an energy equivalent amount of NG which corresponds to 3.09 g CO2e/MJ NExBTL®

13 STEAM CONSUMPTION & PRODUCTION

The Neste Oil Singapore plant is located in the Tuas industrial area which is adjacent to the Tuas power plant. The process steam used in the Neste Oil NExBTL® Singapore plant is produced in a natural gas boiler in the Tuas Power Plant and utilizes natural gas both from the natural gas network and the low pressure (LP) propane rich off gas is from the NExBTL Singapore plant. As the propane rich off gas is biogenic, only the natural gas contributes to net greenhouse gas emissions.

14 POWER CONSUMPTION

During the period in question electrical power consumption in the Neste Oil Singapore NExBTL® plant was 0.106 kWh/kg NExBTL which was purchased from the Singapore grid.

15 NExBTL® PHYSICAL DELIVERY

NExBTL® is transported from the production plant to a storage tank via pipeline over a distance of less than 1 mile. NExBTL® is transported for loading from the storage tank to the vessel via another pipeline over a distance of less than 1 mile.

NExBTL® is then shipped from Singapore to California discharge ports via ocean-going vessels over an average distance of 7,677 miles. Upon arrival, NExBTL® is discharged from the vessel to the onshore storage tanks via pipeline.

16 PATHWAY CI SUMMARY

The final carbon Intensity of the proposed pathway is summarized in the table 2 below:

Table 2 Pathway CI summary

Neste Oil UCO Pathway	NExBTL, Offgas used in G.H2 production
UCO rendering	0.00
UCO Transport	1.40
Renewable Diesel Production	11.13
Renewable Diesel Transport and Distribution	5.98
Total WTT	18.52
Total TTW	0.78
Propane Rich Off-Gas Credit	-3.09
Total WTW	**16.21**