Introduction to HVO, a premium bio based diesel

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History of Neste Oil
History of Neste Oil

- **1948**: Neste was created to secure Finland’s oil supply
- **1957**: Naantali refinery
- **1965**: Porvoo refinery
- **1995**: Neste listed on the Helsinki Stock Exchange
- **1998**: Neste and IVO merge to form Fortum
- **2005**: Neste Oil spun off from Fortum and relisted
- **2007–2011**: Major investments at Porvoo and in Singapore and Rotterdam
  - The world’s leading producer of renewable diesel today and one of the world’s leading base oil producers
Neste Oil in brief

A refining and marketing company focused on premium-quality traffic fuels

Refining capacity: 15 million t/a of petroleum products and 2 million t/a of renewable diesel

Net sales: €17.9 billion (2012)

Operations in 15 countries; employs approx. 5,000 people

Listed on the Helsinki Stock Exchange

Largest owner: the Finnish State (50.1%)
Neste Oil’s investments to HVO

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<table>
<thead>
<tr>
<th>Location</th>
<th>Capacity</th>
<th>Investment</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porvoo # 1</td>
<td>190,000 t/a</td>
<td>EUR 100 million</td>
<td>2007</td>
</tr>
<tr>
<td>Porvoo # 2</td>
<td>190,000 t/a</td>
<td>&gt; EUR 100 million</td>
<td>2009</td>
</tr>
<tr>
<td>Singapore</td>
<td>800,000 t/a</td>
<td>EUR 550 million</td>
<td>2010</td>
</tr>
<tr>
<td>Rotterdam</td>
<td>800,000 t/a</td>
<td>EUR 670 million</td>
<td>2011</td>
</tr>
</tbody>
</table>

NExBTL-projects
Biobased diesels
Renewable NExBTL – fully compatible with fossil diesel

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Biodiesel (FAME / RME)</th>
<th>Fossil diesel</th>
<th>Renewable diesel (HVO) e.g. NExBTL</th>
<th>Fischer-Tropsch (BTL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetable oils &amp; animal fats (mainly rapeseed oil)</td>
<td>Crude oil (mineral oil)</td>
<td>Flexible mix of raw materials (vegetable oils &amp; waste fats)</td>
<td>Biomass</td>
</tr>
<tr>
<td>Technology</td>
<td>Esterification</td>
<td>Traditional refining</td>
<td>Hydrotreating</td>
<td>Gasification &amp; Fischer-Tropsch</td>
</tr>
<tr>
<td>End product</td>
<td>Ester-based, conventional biodiesel</td>
<td>Hydrocarbon (gasoline, jet fuel, diesel)</td>
<td>Bio-based hydrocarbon (renewable diesel, jet fuel, bionaphta, biopropane)</td>
<td>Bio-based hydrocarbon (renewable gasoline, jet fuel, diesel)</td>
</tr>
<tr>
<td>Chemical composition</td>
<td>O _ / H_3C-O-C-R</td>
<td>C_nH_2n+2 + aromatics</td>
<td>C_nH_2n+2</td>
<td>C_nH_2n+2</td>
</tr>
</tbody>
</table>

FAME = Fatty Acid Methyl Ester, conventional biodiesel
RME = Rapeseed Methyl Ester, conventional biodiesel
HVO = Hydrotreated Vegetable Oil, advanced biofuel i.e. renewable fuel
BTL = Biomass to Liquid
HVO and FAME processes

Hydrotreatment & Isomerization

Hydrotreating unit integrated to oil refinery using existing
- logistics
- energy, hydrogen
- quality control lab
- etc. facilities

Not co-feed of bio with crude oil

Vegetable oils and animal fats

Esterification

Methanol NaOH

Recovery and mixing

Washing

Glycerol

Washwater (soap water)

Ready-for-use biodiesel

Hydrogen

Water

Feed tank

Pretreatment Impurities removal

Bio oils

Solids

HVO -Process Conversion of fatty acids to fuels

Stabilization

Renewable gasoline

Renewable LPG

Renewable diesel fuel

Blending and sales

Hydrotreatment & Isomerization
Contaminants in the raw material

- Vegetable oils contain impurities (eg. P, Mg, Ca, Fe)
  - All impurities have to be efficiently removed in the pretreatment process
  - Remaining impurities will be absorbed by the hydrotreatment catalyst
    - This would shorten the lifetime of the catalyst

No impurities are left in the end product

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration (mg/kg) all below detection limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Ca</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Cr</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Cu</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Fe</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Mg</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Mn</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Mo</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Na</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Ni</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Pb</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>V</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Zn</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>F*</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cl*</td>
<td>&lt;1</td>
</tr>
<tr>
<td>P*</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

*from different HVO batches
Currently used renewable raw materials for HVO production (10 raw materials at the moment)

- Palm oil
- FAD: Stearin, palm fatty acid distillate
- Waste animal fat from the food industry
- Waste fat from fish processing industry
- Camelina oil
- Jatropha oil
- Soybean oil
- Rapeseed oil

Neste Oil also procures bio-based ethanol from the global market to be used as a bio-component in 95 E10 and 98 E5 gasoline.
Expanding the feedstock base for HVO

- Waste animal fats, waste oils, residue and side streams
- Microbial oil
- Non-food vegetable oils
- Harvesting residue and biomass
- Algae oil

Short term | Long term (2015-)

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Fuel properties
### Typical fuel properties

<table>
<thead>
<tr>
<th></th>
<th>EN 590 diesel (summer)</th>
<th>TS 15940 HVO NExBTL</th>
<th>EN 14214 FAME (rape seed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density (kg/m³)</strong></td>
<td>≈ 835</td>
<td>≈ 785</td>
<td>≈ 885</td>
</tr>
<tr>
<td><strong>Cetane number</strong></td>
<td>≈ 53</td>
<td>75 ... 99</td>
<td>≈ 51</td>
</tr>
<tr>
<td><strong>Distillation range (°C)</strong></td>
<td>180 ... 360</td>
<td>180 ... 320</td>
<td>350 ... 370</td>
</tr>
<tr>
<td><strong>Heating value (MJ/l)</strong></td>
<td>≈ 35.7</td>
<td>≈ 34.1... 34.4</td>
<td>≈ 33.2</td>
</tr>
<tr>
<td><strong>Total aromatics (wt-%)</strong></td>
<td>≈ 30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Oxygen (wt-%)</strong></td>
<td>0</td>
<td>0</td>
<td>≈ 11</td>
</tr>
<tr>
<td><strong>Stability</strong></td>
<td>Ok</td>
<td>Ok</td>
<td>Challenge</td>
</tr>
<tr>
<td><strong>Ash, metals</strong></td>
<td>Ok</td>
<td>Ok</td>
<td>Challenge</td>
</tr>
<tr>
<td><strong>Cold operability</strong></td>
<td>Ok</td>
<td>Ok</td>
<td>Challenge</td>
</tr>
<tr>
<td><strong>In diesel fuel (vol-%)</strong></td>
<td>... 30 ... 100</td>
<td>... 7 (... 10?)</td>
<td></td>
</tr>
</tbody>
</table>
## Properties of diesel fuels

<table>
<thead>
<tr>
<th></th>
<th>S-free EN590 diesel fuel</th>
<th>HVO BTL GTL (even 100 %)</th>
<th>If not ok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur content</td>
<td>OK</td>
<td>OK</td>
<td>Aftertreatment operation</td>
</tr>
<tr>
<td>Distillation range</td>
<td>OK</td>
<td>OK</td>
<td>Engine oil dilution</td>
</tr>
<tr>
<td>Stability</td>
<td>OK</td>
<td>OK</td>
<td>Deposits in fuel system</td>
</tr>
<tr>
<td>Ash, metals</td>
<td>OK</td>
<td>OK</td>
<td>Aftertreatment durability</td>
</tr>
<tr>
<td>Cold properties</td>
<td>OK</td>
<td>OK</td>
<td>Fit for purpose all the year round</td>
</tr>
</tbody>
</table>

HVO = hydrotreated vegetable oil  
BTL = bio-to-liquids from biomass by Fischer-Tropsch  
GTL = gas-to-liquids from natural gas by Fischer-Tropsch
Typical properties

- NExBTL is produced from vegetable oils or animal fats via hydrogenation and isomerisation.
- NExBTL is free from aromatics, sulphur and metals.
- Contains only n- and i-paraffin with carbon number (C10-C20), distillation mainly 180-320 °C
- Lighter than EN590 due of these facts.
- Clear and bright, colourless
Typical properties

- Feedstock has a very little effect to NExBTL properties. Feedstock does not have an influence the cold properties.
- High cetane number > 70.
- Viscosity (at 40°C) similar than fossil diesel (~2.3-3.5 mm²/s).
- Production process control flashpoint (>61 °C) and cold properties.
- Lubricity additive or FAME (~2 vol%) will be needed to achieve lubricity requirement. NExBTL without additive HFRR is about 650 µm which is similar like fossil diesel without additive.
Blending properties
Blending properties

- NExBTL can be easily blended with EN590, because NExBTL contains only n- and i-paraffins similar molecules than in diesel. Same consideration have to be make than blending two fossil diesels (temperature of the fuels, lighter first to bottom etc.)
- By blending NExBTL to diesel you can achieve several benefits
  - Reduce aromatic and sulphur content and increase cetane number. Also benefits from distillation (lower end point than EN590). Cold properties can be tailor made.
Blending properties

- Same additives (lubricity, conductivity etc) than in mineral diesel can be used with NExBTL.
- Limitations to EN590 is only density, summer grade ~30 v% of NExBTL can be blended to have density higher than 820 kg/m$^3$, for arctic grades even 50 v% can be blended (limit min 800 kg/m$^3$)
- Same logistics can be used for HVO than fossil diesel no risk of contamination (for example pipelines where JET is transferred)
Distillation of biofuel blends

GC distillation for better accuracy near 0 % and 100 %

=> Do not compare °C-values to standard distillation


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Benefits with blending

Indicative NExBTL diesel blending table for EN590 CETANE NUMBER

- Base diesel cetane number
- EN 590 minimum limit

- Blue = NExBTL diesel with cetane number of 90
- Pink = NExBTL diesel with cetane number of 80
- Green = NExBTL diesel with cetane number of 70

NExBTL diesel with required to upgrade the base diesel to minimum limit of EN 590 cetane number.
Indicative NExBTL diesel blending table for EN590 DENSITY

- NExBTL diesel amount required to upgrade the base diesel to EN 590 maximum density limit
- Maximum NExBTL diesel amount that fits to the base diesel before going over the EN 590 density limit for summer diesel
- Maximum NExBTL diesel amount that fits to the base diesel before going over the EN 590 density limit for winter diesel (CP -10°C or better, CFPP -20°C or better)
Benefits when blending

Minimum amount (vol.%) of NExBTL needed to blend the fossil diesel to EN 590 spec

polyaromatic content of diesel fuel

0.00 %  5.00 %  10.00 %  15.00 %  20.00 %  25.00 %  30.00 %  35.00 %  40.00 %  45.00 %  7  8  9  10  11  12  13  14  15
Blending with FAME blends

- NExBTL can be added to EN590 + 7% FAME blend. It is important to know quality of the FAME (content of saturated monoglycerides) and aromatic content of the mineral diesel. Swedish class 1 (total aromatics max 5 V/V%) can tolerate up to 7 vol% high quality RME, meaning ~20 ppm saturated monoglyceride content. Same rule can be used for pure HVO.
- It is not recommended to store NExBTL and FAME in same tank (up to 7%V/V good quality FAME can be blended with NExBTL). FAME’s impurities like saturated monoglycerides might precipitate in cold temperature above cloud point in low aromatic diesels.
- If blending is made in tank farm, it is recommend to blend first fossil diesel and NExBTL (chemically close to each other) and after that FAME is added to final blend.
Emissions
Emission with HVO compared to EN590

- CO
- HC
- NOx
- Particulates
- CO2

32 Trucks & buses, HVO
2 Cars, HVO
6 Cars, 85% HVO

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All the renewable raw materials that Neste Oil uses in refining offer the users of NExBTL renewable diesel an opportunity to reduce greenhouse gas emissions by 40–90% compared to fossil diesel.

<table>
<thead>
<tr>
<th></th>
<th>GHG emissions during the entire life cycle (g CO₂ eq/MJ)</th>
<th>GHG emission reduction during the entire life cycle (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil diesel</td>
<td>83.8</td>
<td></td>
</tr>
<tr>
<td>NExBTL diesel produced from palm oil</td>
<td>44.8</td>
<td>47%</td>
</tr>
<tr>
<td>NExBTL diesel produced from rapeseed oil</td>
<td>42.8</td>
<td>49%</td>
</tr>
<tr>
<td>NExBTL diesel produced from waste animal fats</td>
<td>20.5</td>
<td>91%*</td>
</tr>
</tbody>
</table>

*When classified as waste or residue
Useful info:

- HVO handbook
Thank you.

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