Converting MSW Into Low-Cost, Renewable Jet Fuel

CAAFI Biennial General Meeting & Integrated ASCENT Symposium

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Fulcrum: Solving Two Global Challenges

Waste Disposal

Decarbonization of Air Transportation
Fulcrum – MSW to Renewable Fuels

- Long-Term Feedstock Supply – Input Costs Locked In
- Long-Term Offtake Agreements
- Guaranteed Technology Process
- Strong Strategic Investor Group
- First Project Financed and Under Construction
- Standardized Projects – Design, Contracts, Financing
Changing the way Garbage is Handled and Disposed

- Large Volumes, Ideal Locations
- Established Infrastructure
- Carbon-Rich Feedstock Ideal for Biofuel Production
- Predictable Cost
- No Competing Uses
- Resolves Waste Disposal Problems
Proprietary, Proven & Efficient Fuels Process

Feedstock Processing Facility Prepares MSW for Fuels Process

Steam Reforming Gasification System Converts MSW to Synthesis Gas

Fischer-Tropsch Process Converts Synthesis Gas to Syncrude, Jet Fuel and Diesel
Fulcrum’s Strategic Partner Model

1. Feedstock Supply
2. Waste to Syncrude
3. Fuel Refining
4. Fuel Logistics
5. Customers

Partners:
- Waste Connections, Inc.
- ABENGOA
- bp
- UNITED
- CATHAY PACIFIC
- WASTE MANAGEMENT
- Marubeni
- JAPAN AIRLINES
- andeavor
- World Fuel Services
Sierra BioFuels Plant
Feedstock Processing Facility

- Feedstock Processing Facility In Operations; Construction Completed on Schedule and on Budget
- Converts 350,000 Tons of Raw Waste into 175,000 Tons of Processed Feedstock per Year
- Waste Processing Capacity up to 120 Tons per Hour
Sierra BioFuels Plant
Bioresinry

- Biorefinery Under Construction
- 175,000 Tons of Processed MSW Feedstock Converted to 11 Million Gallons of Low-Carbon Transportation Fuel Each Year
- Plant Operations Begin in Early 2020
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Red Rock Biofuels

Growing Jet and Diesel Fuel Consumption

- 50% more jet fuel by 2040
- 30% more diesel fuel by 2040

Transportation Sector Major Source of CO₂ Emissions


Government Regulation Targeting High Volumes of Renewable Fuels

- RFS2 & LCFS: EPA and CARB¹ programs to increase renewable fuel production

Focus on Carbon Emissions in the Aviation Sector

- CORSIA framework to start voluntary (2021+) and mandatory (2026+) CO₂ reductions for international aviation

Increasing Demand for Advanced Biofuels

- 288mm gallons of mandated cellulosic biofuels in 2018
- CORSIA Goal: carbon neutral growth from 2020 onwards

Red Rock Biofuels produces unique products in high demand

- 15mm gallons per year of biofuels

Source: Exxon Mobil 2017 Outlook for Energy, United States Environmental Protection Agency, ICAO.

¹ EPA corresponds to the United States Environmental Protection Agency and CARB to the California Air Resources Board.
Global Climate Change Imperative

- Transportation sector already major source of CO2 emissions (27%)
- Growing population and standard of living will increase jet & diesel fuel use:
  - 30% more diesel fuel by 2040
  - 50% more jet fuel by 2040

Credit: International Energy Agency, World Energy Outlook 2016; Exxon Mobil 2017 Outlook; U.S. Environmental Protection Agency
Process Technology

A. Gasification
   Produce syngas (CO & H₂)

B. Fischer-Tropsch
   Form hydrocarbon chains

C. Hydroprocessing
   Upgrade into finished fuels

136,000 bdt/yr Woody Biomass
+ temp & pressure
15.1 MGY
Renewable, Drop-In Heavy Transport Fuels

20% Naphtha
40% Jet
40% Diesel

40% Jet
20% Naphtha

15.1 MGY
Renewable, Drop-In Heavy Transport Fuels
Project Overview

Project and Site
- Advanced biofuels production facility converting woody biomass into renewable drop-in jet, diesel, and gasoline blendstock fuels
  - Conversion of ~136,000 BDT/year of woody biomass into ~15.1mm gallons/year of renewable cellulosic fuels

Feedstock
- 70% of annual feedstock requirement under long term contract

Offtake
- Jet Fuel: 100% of jet fuel to be sold to FedEx and Southwest

EPC
- EPC Contract with IR1 Group LLC

Technology
- Gasification and Syngas Clean-Up Unit: conversion of woody biomass to syngas
- Fischer-Tropsch Unit: cleaned syngas converted into Fischer-Tropsch (FT) waxes and liquids
- Upgrading of FT Products: upgrading of FT Products into finished fuel products

Facility Location

Biofuels Breakdown (by Production Volume)
Facility requires 136,000 BDT of woody biomass per year
—Corresponds to ~18% of total waste wood produced within 125 mile radius

Minimal regional competition for forest biomass material within 125 mile radius
Plant Layout
Views of the Site
Schematic
Project Schedule

- **Engineering and Procurement**
  - Place Major Equipment Orders
  - Full Notice to Proceed (Engineering)
  - Complete Detailed Engineering

- **Material Handling Area**
  - Construction

- **Gasifier (TCG)**
  - Gasifier Purchase
  - Gasifier Fabrication
  - Gasifier Installation

- **Fischer Tropsch Unit (Velocys)**
  - FT Unit Purchase
  - FT Module & Reactors Fabrication
  - FT Module & Installation

- **Product Upgrading (Haldor Topsoe)**
  - Upgrading Purchase
  - Upgrading Area Module Fabrication
  - Upgrading Unit Installation

- **Power Island & Syngas Compressor**
  - Steam Turbine Generator Purchase and Fabrication
  - Auxiliary Boiler Purchase and Fabrication
  - Syngas Compressor Purchase and Fabrication

- **Balance of Plant Area**
  - Plant Area Construction

- **Timeline**
  - 2018: Apr May Jun Jul Aug Sep Oct Nov Dec
  - 2019: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
  - 2020: Jan Feb Mar

- **Key Events**
  - Mechanical Completion
  - Performance Tests
  - Final Completion

- **Area**
  - Gasifier (TCG)
  - Fischer Tropsch Unit (Velocys)
  - Product Upgrading (Haldor Topsoe)
  - Power Island & Syngas Compressor
  - Material Handling Area
  - Balance of Plant Area
Expansion

Production Potential, by county

Credit: USDA BioSys database, 2015
Thank You
Neste Aviation Solutions

Presented at the CAAFI Biennial General Meeting
“The Producer Pack” - plans for production and expansion

Washington DC, December 4, 2018
Discussion points

Neste in brief
Renewable jet fuel
  • Go to market approach
  • Feedstock and sustainability
The Future
  • Renewable chemicals and plastics
  • Plastics to fuel
Safe Harbor Statement

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Neste in brief
Neste by numbers

260,000 bbl/day petroleum refining

910 Million gallons/year Renewable Diesel

Comparable operating profit $1.4B (2017)

5,000 professionals in 15 countries

$49 million annual R&D spend
Neste has a strong history of developing, commercializing, and marketing new fuels

- **1980-2005**: Lead-free & sulfur-free fuels
- **2007**: Renewable diesel
- **2011**: Renewable jet fuel
- **2013**: ProDiesel
- **2014**: Futura premium gasoline
- **2015**: Low-sulfur marine fuel
- **2018**: Renewable propane
- **2018**: Renewable chemicals
- **Future**: Green Hub Plastics to fuels

Neste has a strong history of developing, commercializing, and marketing new fuels.
Neste’s Renewable products refineries

- PORVOO
  - #1 and #2
  - 135 million gpy

- SINGAPORE
  - 405 million gpy

- ROTTERDAM
  - 370 million gpy

FID for Singapore expansion for additional 340 million gpy will be made later this month
Renewable Jet Fuel: A solution for sustainable aviation
Despite numerous test programs and commercial launch, widespread continuous use of RJF has not been achieved.
Creating value through delighting customers of different stakeholders

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<tr>
<th>AIRLINES</th>
<th>AIRPORTS</th>
<th>GOVERNMENT</th>
<th>FUEL PRODUCERS</th>
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<tr>
<td>• RJF has higher fuel energy density (by mass)</td>
<td>• Helps fight climate change</td>
<td>• Improved air quality &amp; living standards</td>
<td>• Enhanced product portfolio, energy diversification and value proposition to customers</td>
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<td>• RJF has better thermal stability</td>
<td>• Meet GHG reduction targets - e.g. Airport Carbon Accreditation</td>
<td>• Meet global GHG reduction targets</td>
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<td>• Recognition as a model corporate citizen</td>
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<td>• Support R&amp;D of renewable jet fuel and the development of more efficient supply chains</td>
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<td>• Drive new value proposition &amp; associated revenues</td>
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<td>• Legitimacy for growth</td>
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**LOCAL COMMUNITY**

- Improved air quality
- Local responsibility
- Engaged and happy community
- Contribution to fight climate change

**PASSENGERS**

- Ability to make an impact for change
- Lower carbon footprint
- Brand loyalty and brand ambassadors
- Recognition as a responsible citizen

**CORPORATIONS**

- Meet corporate social responsibility goals
- Enhance marketing and PR value
- Reduce business travel footprint
- Attract employees who are demanding sustainable behaviour
Neste cooperation with leading aviation brands

2011
Lufthansa
HEFA used in 1,187 scheduled flights

2014
Testing begins on the HFP HEFA for a new RJF specification

2016
Oslo Gardermoen becomes the world's first airport to offer HEFA to all flights

2018
American Airlines
Multiple collaboration agreements with airlines

2018
DFW
Multiple agreements with airports and others to explore Green Hub and supply chain

2018
SFO
air bp
Collaboration to support supply chain development
Feedstock Sourcing and Certification
Broad range of renewable raw materials

- Animal fat from food industry waste
- Fish fat from fish processing waste
- Vegetable oil processing waste and residues (e.g. PFAD, PES, SBEO)
- Used cooking oil
- Technical corn oil
- Crude palm oil
- Rapeseed oil
- Soybean oil
- Camelina oil
- Jatropha oil
Focus on non-cultivated materials:

- We have technical capability to use all waste and residue
- Current share of w&r is close to 80%
- We continue to research the use of lower quality materials
- R&D spend is approximately 40 million euro per year

Waste and residue usage continues to increase
Expanding our feedstock portfolio

Short term
- Waste animal fats, waste oils, residue and side streams
- Microbial oil

Long term
- Algae oil
- Thermo-chemical pathways
- Plastic liquefaction
All renewable raw materials sustainably produced

- All of the renewable raw materials used by Neste are traced back to the plantations or production plants
- Our contracts include strict sustainability requirements, e.g. human rights, forests, carbon-rich areas covered
- Taking leadership in sustainability practices is essential to growing acceptability of renewable feedstocks
Neste’s Approach to Bio-Based Chemicals

- **Oils and fats feedstock pool**
- **NEXBTL production**
  - Renewable Diesel
  - Steam Cracker
  - Isoalkane Stream
- **Converter**
  - Fuel market (e.g. Petrol Stations, Fleets)
  - Brandowner
  - Brandowner

**Pretreatment**

**Catalytic hydrotreatment H2**

**Catalytic Isomerisation**
Closing the loop for Plastics through chemical recycling
Creating a higher value alternative for incineration and complementing mechanical recycling

Re-use
- Used for same purpose

Material recycling (mechanical)
- Mechanically sorted and re-granulated for use in new products

Chemical recycling
- Used as feedstock in the chemical industry to make plastics and petroleum products

Energy recovery
- Converted to electricity and/or heat by incineration

Reject
- No use, landfilled

Improved collection and sorting creates increasing amount of plastic material that is too poor in quality for mechanical recycling, but too high value to just incinerate.

To be counted to recycling targets
Neste focus on chemical recycling

- Chemical recycling of plastics and end-of-life tires means converting them by liquefaction or gasification to feedstock for the chemical industry.
- This feedstock can be used to replace crude oil in production of fuels, lubricants, bitumen, solvents, and plastics.
Concluding remarks

- Renewable jet fuel must be part of the solution to make air travel more sustainable
- Neste has long had the capability to produce RJF and has now committed to supply the market on a permanent basis
- Neste is collaborating with airlines, airports, and other stakeholders around the world to promote the use of renewable jet fuel
- Neste will continue to increase total renewable fuels capacity, and specifically increase RJF production and sales
- Renewable plastics and plastics to waste fuel will further help to decarbonize aviation in the future - but will need supportive policy to grow

Safe travels - and remember to lower your own environmental footprint!