Central Plant GHG Emissions Reduction Options

- Increase efficiency of existing operations (high efficiency burners, modern controls and/or VFDs)
- Convert from coal to No. 2 oil or gas
- Convert from oil or gas to a biogenic fuel like landfill gas or digester gas.
- Convert from oil or gas to a biogenic fuel like wood waste.
- A new option is available to convert to biogenic Renewable Fuel Oil (RFO)
RFO Conversion at a Glance

- RFO is a liquid biomass fuel made from wood waste products
- Because RFO is considered to be biogenic, greenhouse gas emissions from RFO are 88% lower than heavy oil, and 81% lower than natural gas.
- NOx and CO emissions are similar to natural gas and typically less than No. 2 oil.
- Virtually any firetube or watertube boiler can be converted to fire RFO.
- Firing RFO is similar to any fuel oil requiring pre-heating (No. 6 oil or No. 4 oil)
- Cost per Btu is less than No. 2 oil, but typically more expensive than natural gas
## Typical GHG “life cycle” GHG Factors for Combustion

<table>
<thead>
<tr>
<th>Energy Component</th>
<th>GHG emission factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>207 #/MMBTU</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>141 #/MMBTU</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.7 to 1.6 #/kwh</td>
</tr>
<tr>
<td>RFO</td>
<td>25.7 #/MMBTU</td>
</tr>
</tbody>
</table>
Current RFO Users

- Memorial Hospital
- Youngstown Thermal
- Bates College
Objective was to reduce costs and be “green”

Contract for long term supply of RFO signed April, 2014, first deliveries began summer of 2014.

Designed to operate on RFO with #4 oil backup. Provides fuel optionality

First winter was coldest Feb. on record, and RFO was exclusive fuel.

RFO has been the primary fuel since August of 2014

Annual RFO use is approximately 300,000 gallons. First year target savings of $160,000 realized
Memorial Hospital

- Two 200 HP Cleaver Brooks boilers
- Retrofits installed
  - 15,000 gallon free standing double walled SS storage tank
  - RFO unloading module
  - Fuel delivery system
  - 2 Cleaver Brooks OEM RFO/4 oil burners- 8.45 MMBTU/hr each
  - Cleaver Brooks control system
- Operational plan - RFO as primary fuel, with 4 oil backup
- Efficiency over 87% - <4 ppm CO levels- good combustion
- Over 700,000 gallons of RFO consumed to date
- Approximate GHG reduction 24,000 MT
RFO Easily Integrated with Existing Infrastructure

- 15,000 gallon stainless steel storage tank
- Fuel unloading module
- Insulated above ground piping

- Cleaver Brooks OEM dual fuel burners
- Redundant fuel piping
- Integrated CB controls
Memorial Hospital Delivery System, Burner and Controls
Youngstown Thermal

- 4 boilers - nominal 120,000 MMBTU hour heat input
  - 3 coal, 1 natural gas
  - Converted natural gas boiler to dual fuel - Nat gas/ RFO

- Retrofit includes
  - 40,000 gallon single wall SS storage tank, with containment
  - 2 nominal 60 MMBTU/hr dual fuel burners
  - Fuel delivery skid

- Marked efficiency improvement - low CO levels
- Full commercial operations - savings being realized
Youngstown Thermal Retrofit
Youngstown Thermal Fuel Delivery System
Youngstown Thermal Dual Fuel Burners

- Burners designed for natural gas and RFO—any combination
- Two burners fired into one furnace – each with a nominal capacity 60MMBTU/hr
- Third party source tested at 65 ppm NOx, 0.2 ppm SO2, 3.1 ppm CO, and 0.1 ppm VOC
Youngstown Thermal MCC, BMS, and Controls
Youngstown Thermal RFO Fuel Guns
• Signed ACUPCC pledge May 16, 2007
• Pledge date for Carbon neutrality 2020
• Scope 1 GHG emissions were approximately 40% of total of Scope 1-3
• Central steam plant represents approximately 70% of the Scope 1 emissions
• Committed to initially replace ~ 70% of fuel mix at CP with RFO, added fuel redundancy

• Resulted initially in an annual reduction of over 80% of CP GHG emissions from 3080 MTCO2e to 532 MTCO2e
• Bates will additionally save > $600,000 over the life of the contract
Bates College

- 3-700 HP boilers, natural gas and 2 oil fired
  - Conversion of 1 boiler initially, with plans to convert a second boiler. Preferred Utility burner integrated with existing Preferred Utilities controls
  - Fuel delivery skid sized for 2 boilers
  - 20,000 gallon double wall SS storage tank
  - Steam to hot water module
- Operational plan is to run one boiler on RFO, 2 boilers on standby on natural gas and 2 oil - anticipate this will be sufficient for all but very peak loads.
- Fully operational - < 4 ppm CO - running at 85%+ efficiency
Burner Assembly – 29.4 MMBTU per hour
Fuel Delivery Skid & Storage Tank

- Duplex pumps & strainers
- Heat exchanger
- Motor control center
- Instrumentation
- Recirculation valving
- Separate fuel unloading skid

- Double wall storage tank (20,000 gallon of capacity)
- High and low level alarms
- Flame Arrestor
Feedstock Requirements

- Feedstock comes from either harvest residues or commercial thinnings from a sustainably managed forest.
- Harvest residues would most likely either be left in the forest or burned in the forest if not used for RFO.
- Forester is required to provide an affidavit that feedstock has met the above criteria and that the feedstock did not originate from environmentally sensitive land or government owned land.
- Each batch of fuel has a certificate that follows it which details where the feedstock originated.
- Our feedstock suppliers are generally larger logging operations because they have the ability to provide the necessary certification for the RFS2 program.
RFO Produces Significant Environmental Benefits

- RFO is a direct substitute for fossil fuels
- RFO provides fiber owners with an opportunity to enhance their sustainable forest management practices
- Greater use of sustainable forest management practices reduces the wildfire risk to timber and forest stands
- RFO is considered to be “biogenic’ for GHG emission purposes
Woody Biomass to High Value Products

Biomass Feedstock

Conversion to Liquid Biocrude

- RTP Process

Biocrude Refinery Feedstock

Chemical Feedstock

Renewable Fuel Oil

Food Ingredients & Renewable Chemicals

Heating & Cooling

Refinery Co-processing

Biocrude Refinery
What is RFO?

- RFO is a homogeneous, organic liquid obtained from the thermal conversion of biomass
- Has the appearance of motor oil
- It is polar in nature and does not readily mix with hydrocarbons
- pH >2.5, specific gravity of 1.2
- Contains less metals and sulfur than petroleum liquids
- Accepted as a biogenic fuel

**RFO Specification Sheet**

<table>
<thead>
<tr>
<th>Property</th>
<th>Analytical Method</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Content</td>
<td>ASTM E203 (Karl Fisher titration)</td>
<td>&lt;24 wt%</td>
</tr>
<tr>
<td>pH</td>
<td>ASTM E70-07</td>
<td>&gt;2.5</td>
</tr>
<tr>
<td>Density @ 15 ºC</td>
<td>ASTM D4052</td>
<td>10.0 lb/USgal</td>
</tr>
<tr>
<td>Specific Gravity @ 15 ºC</td>
<td></td>
<td>1.20</td>
</tr>
<tr>
<td>Kinematic Viscosity @ 40 ºC</td>
<td>ASTM D445</td>
<td>25 cSt</td>
</tr>
<tr>
<td>Higher (Gross) Heating Value, Moisture Free</td>
<td>ASTM D240</td>
<td>9905 Btu/lb</td>
</tr>
<tr>
<td>Higher (Gross) Heating Value, As-Is</td>
<td>Calculated</td>
<td>7528 Btu/lb</td>
</tr>
<tr>
<td>Lower (Net) Heating Value</td>
<td>Calculated</td>
<td>6842 Btu/lb</td>
</tr>
<tr>
<td>Solids Content</td>
<td>ASTM D7579</td>
<td>0.1 wt%</td>
</tr>
<tr>
<td>Pour Point</td>
<td>ASTM D67</td>
<td>-13 ºF</td>
</tr>
<tr>
<td>Elemental Analysis (moisture &amp; ash free)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>ASTM D6291</td>
<td>54.87 wt%</td>
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<tr>
<td>Hydrogen</td>
<td>ASTM D6291</td>
<td>6.67 wt%</td>
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<tr>
<td>Nitrogen</td>
<td>ASTM D6291</td>
<td>0.16 wt%</td>
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<tr>
<td>Sulphur</td>
<td>ASTM D4294</td>
<td>&lt;0.05 wt%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Calculated, by difference</td>
<td>38.25 wt%</td>
</tr>
<tr>
<td>Ash</td>
<td>ASTM D482</td>
<td>&lt;0.15 wt%</td>
</tr>
</tbody>
</table>
RFO – Made Elsewhere but Will Be Stored Locally

- Existing facility outside of Ottawa Ontario, Quebec facility comes on line in late 2017
- Current projects under development are located in three distinct regions - [7] states in the US
- Initial RFO volumes will be made outside of Massachusetts but will be stored in the immediate vicinity. No different than petroleum-based heating oils that are stored in Boston Harbor, Portsmouth, etc.