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)**

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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 then 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**

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Typical GHG “life cycle“ GHG Factors for Combustion

Energy Component	GHG emission factor
Oil	207 #/MMBTU
Natural Gas	141 #/MMBTU
Electricity	0.7 to 1.6 #/kwh
RFO	25.7 #/MMBTU

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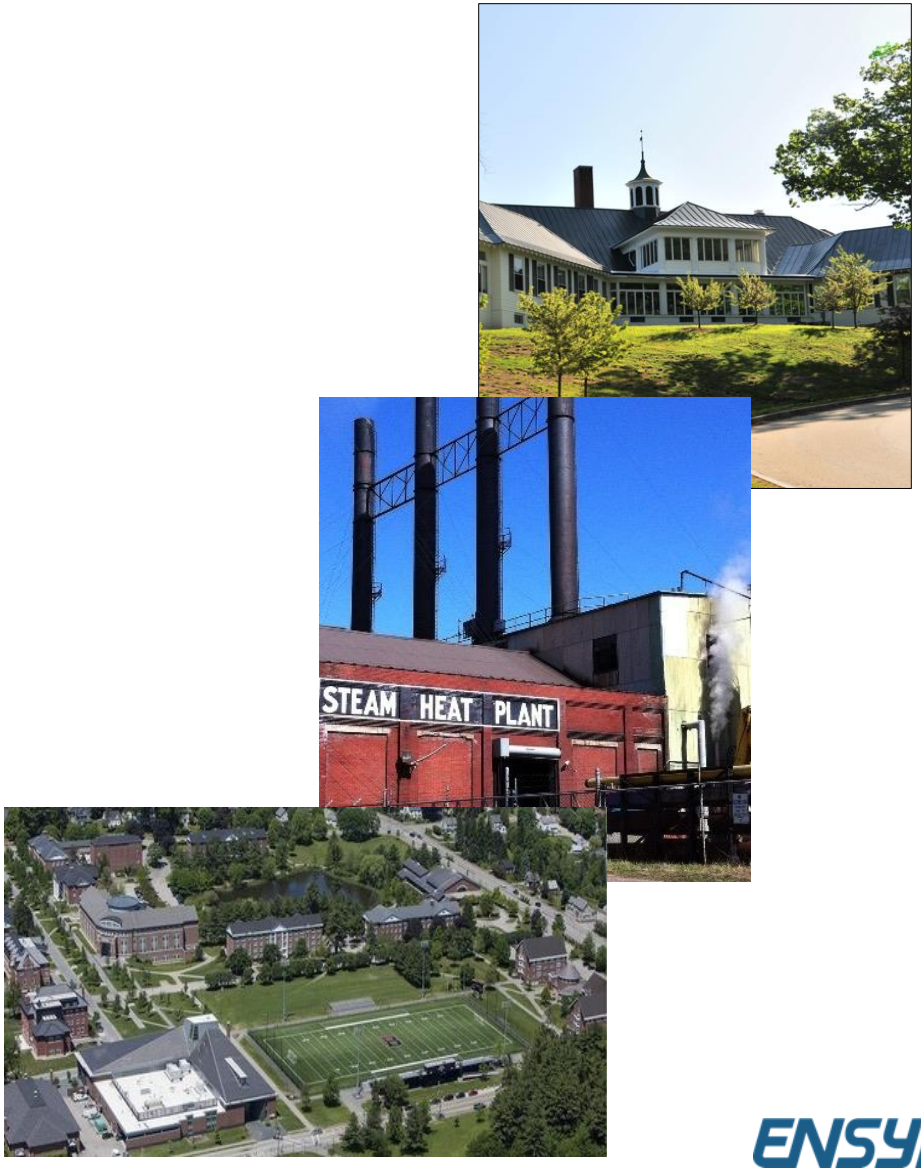
Current RFO Users

- Memorial Hospital
- Youngstown Thermal
- Bates College



Memorial Hospital
North Conway, NH

- 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

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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

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Memorial Hospital Delivery System, Burner and Controls

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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

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Youngstown Thermal Retrofit

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Youngstown Thermal Fuel Delivery System

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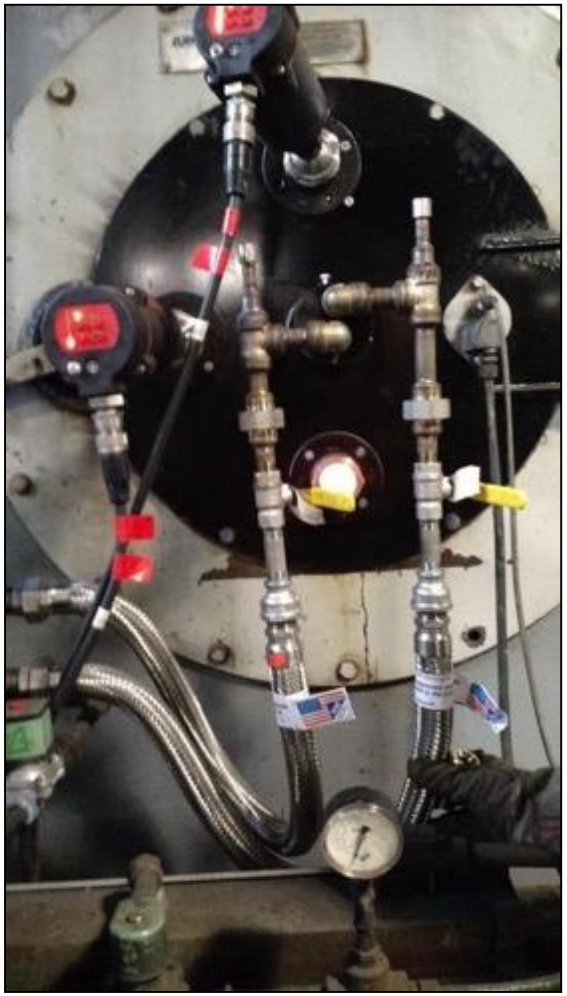
Youngstown Thermal Dual Fuel Burners



- 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 SO_2, 3.1 ppm CO, and 0.1 ppm VOC

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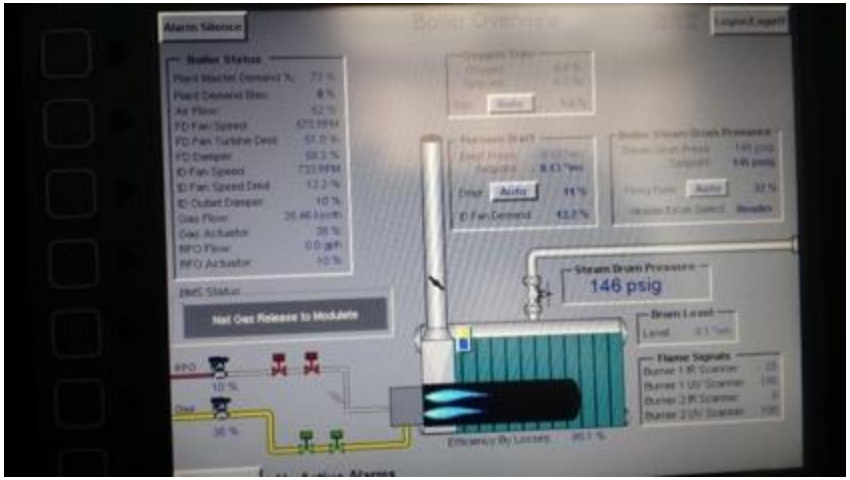
Youngstown Thermal MCC, BMS, and Controls



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Youngstown Thermal RFO Fuel Guns

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Bates College
Lewiston, Maine

- 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

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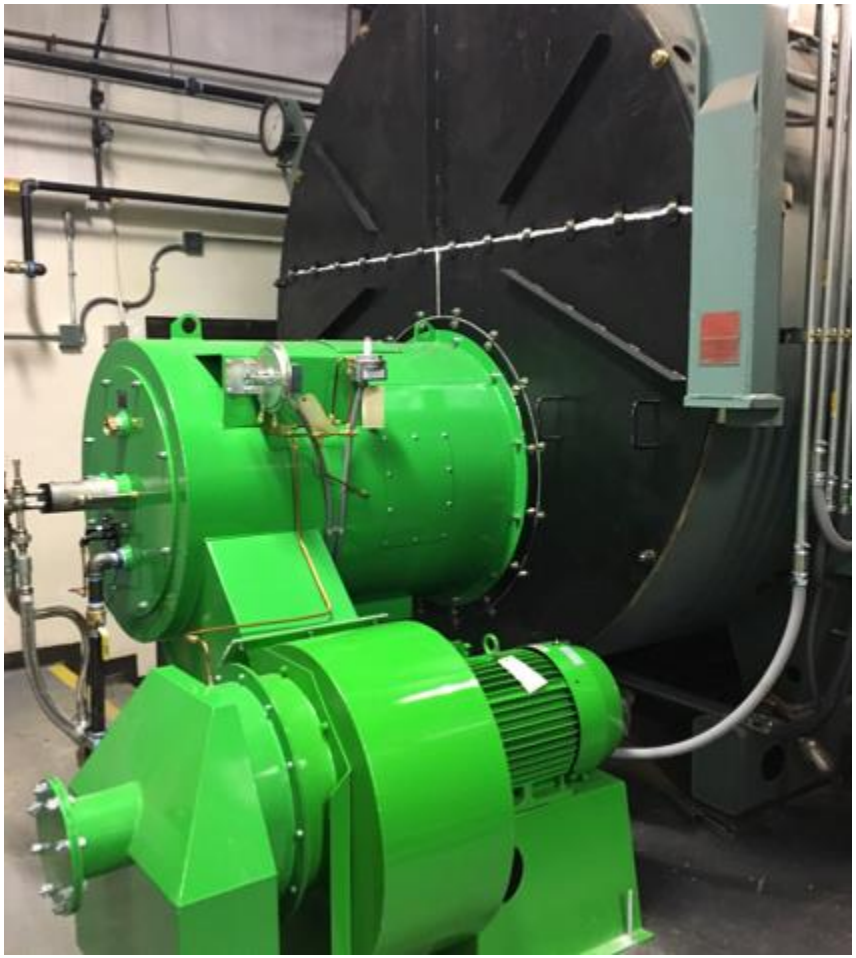
Burner Assembly – 29.4 MMBTU per hour



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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

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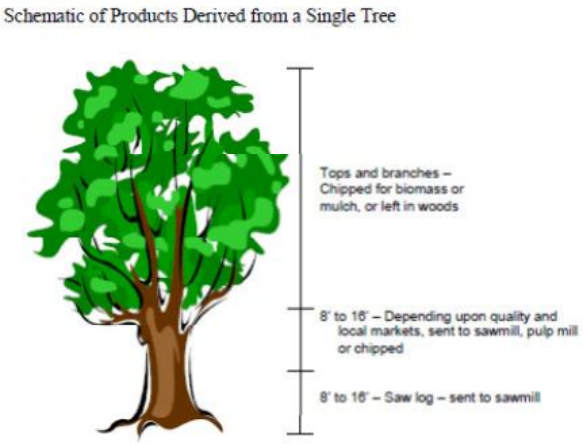
Feedstock Requirements

- 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.



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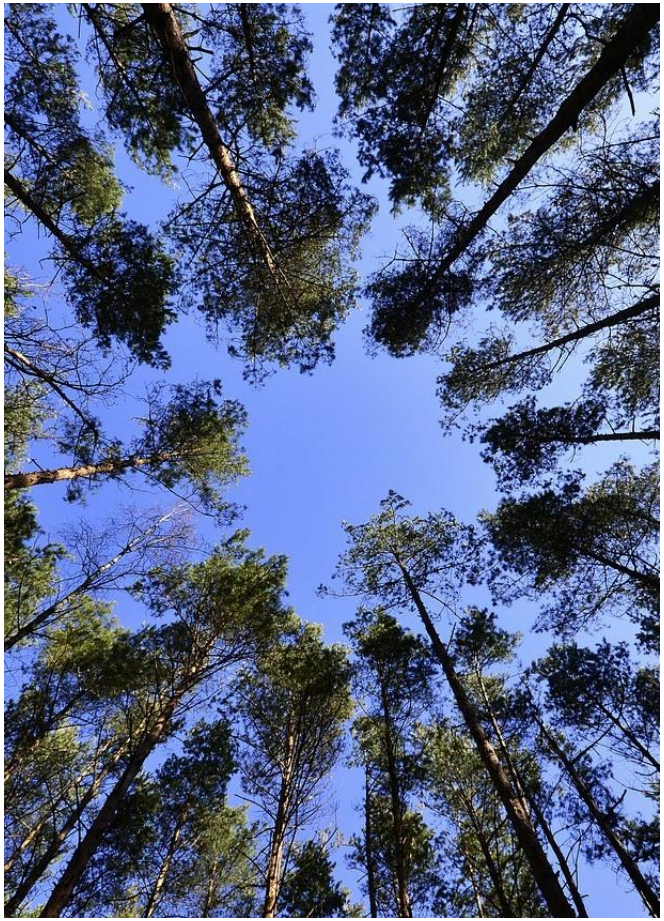
RFO Produces Significant Environmental Benefits

- 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



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Woody Biomass to High Value Products

Biomass Feedstock

Conversion to Liquid Biocrude

RTP Process

Chemical Feedstock

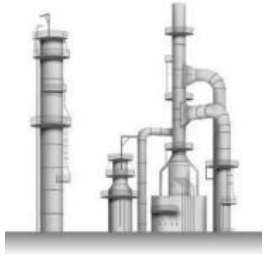
Food Ingredients & Renewable Chemicals

Renewable Fuel Oil

Heating & Cooling

Biocrude Refinery Feedstock

Refinery Co-processing



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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

Property	Analytical Method	Typical
Water Content	ASTM E203 (Karl Fisher titration)	<24 wt%
pH	ASTM E70-07	>2.5
Density @ 15 °C	ASTM D4052	10.0 lb/USgal
Specifc Gravity @ 15 °C		1.20
Kinematic Viscosity @ 40 °C	ASTM D445	25 cSt
Higher (Gross) Heating Value, Moisture Free	ASTM D240	9905 Btu/lb
Higher (Gross) Heating Value, As-Is	Calculated	7528 Btu/lb
Lower (Net) Heating Value	Calculated	6842 Btu/lb
Solids Content	ASTM D7579	0.1 wt%
Pour Point	ASTM D97	-13 °F
Elemental Analysis (moisture & ash free)		
Carbon	ASTM D5291	54.87 wt%
Hydrogen	ASTM D5291	6.67 wt%
Nitrogen	ASTM D5291	0.16 wt%
Sulphur	ASTM D4294	<0.05 wt%
Oxygen	Calculated, by difference	38.25 wt%
Ash	ASTM D482	<0.15 wt%

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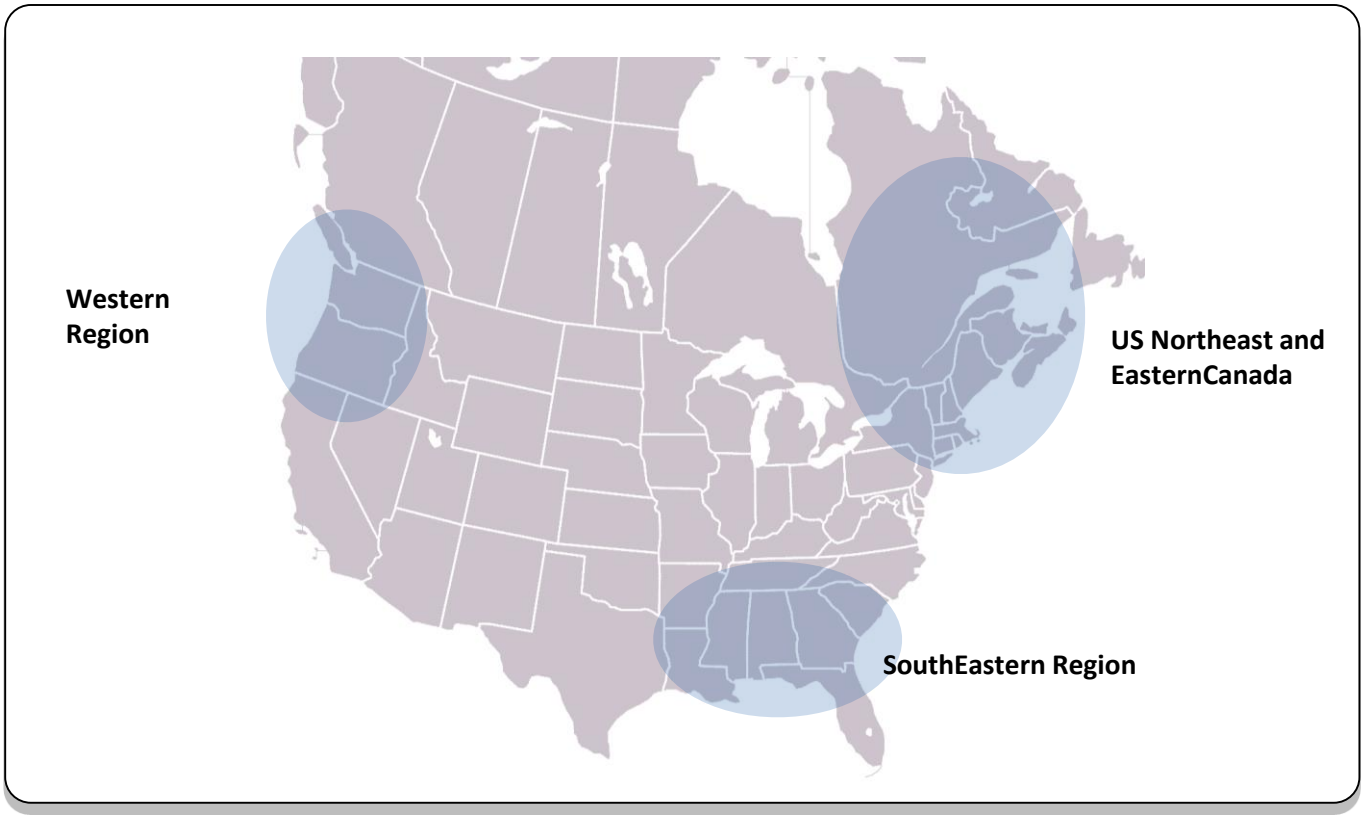
RFO – Made Elsewhere but Will Be Stored Locally

- 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.



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