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Decarbonizing District Energy Systems

CampusEnergy 2017

February 20-24, 2017 Miami Florida

www.ensyn.com

Ensyn's Business – Woody Biomass to High Value Products

Biomass Feedstock

Conversion to Liquid Biocrude

RTP Process

Chemical Feedstock

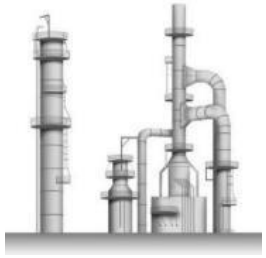
Food Ingredients & Renewable Chemicals

Renewable Fuel Oil

Heating & Cooling

Biocrude Refinery Feedstock

Refinery Co-processing



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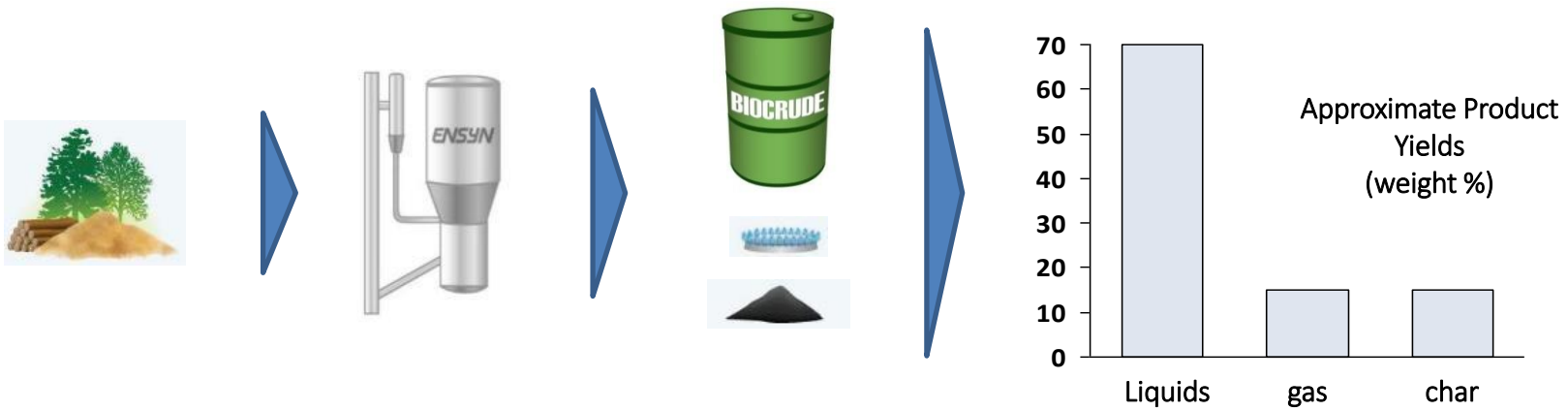
Ensyn's RTP® Technology



- Not "severe" – a non-catalytic, thermal process
- Similar to Fluid Catalytic Cracking as used in petroleum refineries
- No need for catalysts, high pressure or hydrogen
- Gas and char used to run the facility and dry the biomass (energy self-sufficient)
- 35 patents issued, 97 pending
- 16 facilities commissioned over last 25 years, six commercial facilities currently in operation, a seventh under construction (CAD100 million project in Quebec)

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
- Pourable at room temperatures
- Contains ~ 50% the energy density of Light Fuel Oil (#2)
- Meets worldwide specification for pyrolysis oil (ASTM D7544 developed specifically for industrial burner applications)
- Accepted as a biogenic fuel

RFO Specification Sheet

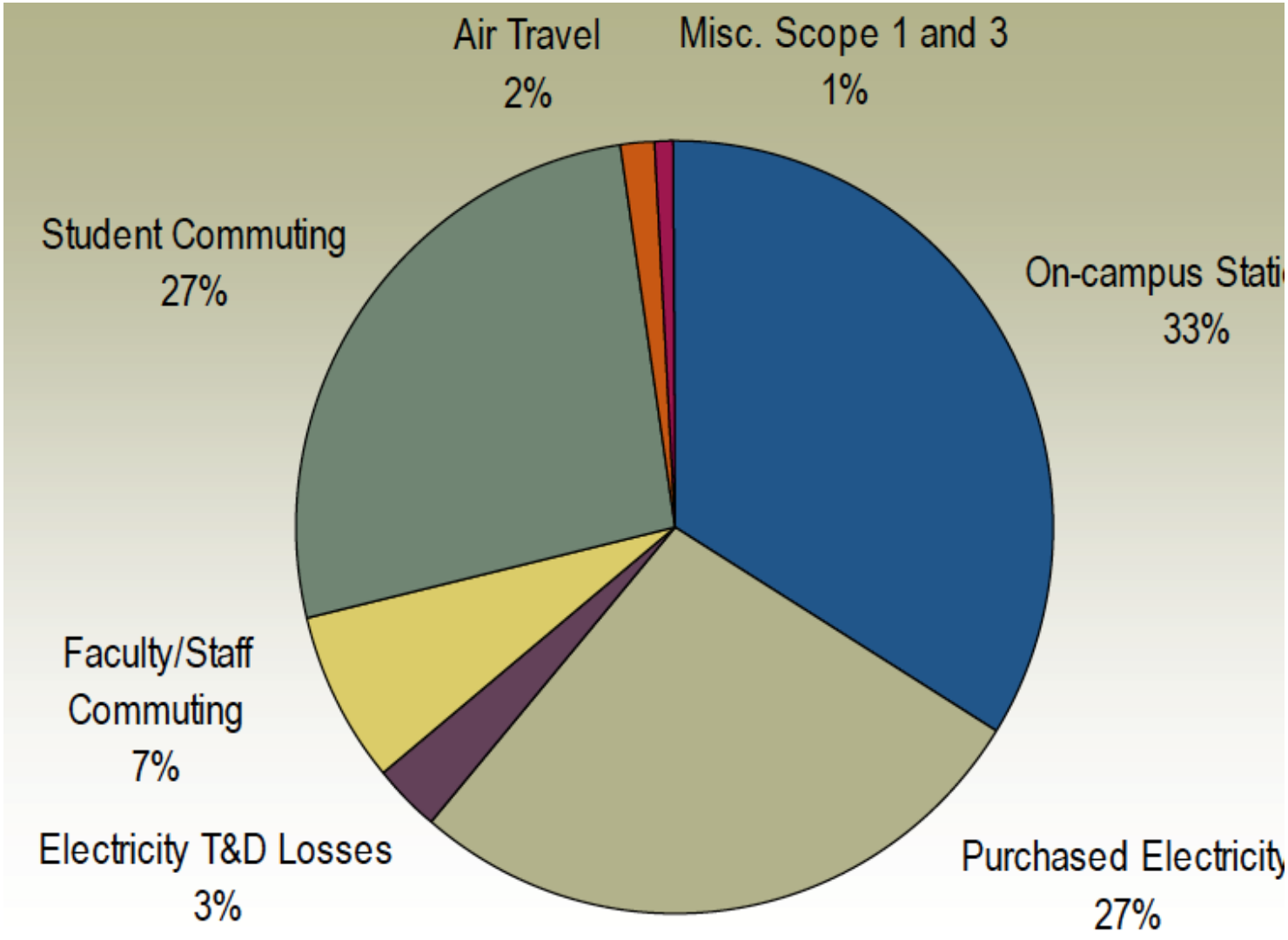
Property	Analytical Method	Typical
Water Content	ASTM E203 (Karl Fisher titration)	<24 wt%
pH	ASTM E70-07	>2.5
Density @ 15 °C	ASTM D4052	10.0 lb/USgal
Specifc Gravity @ 15 °C		1.20
Kinematic Viscosity @ 40 °C	ASTM D445	25 cSt
Higher (Gross) Heating Value, Moisture Free	ASTM D240	9905 Btu/lb
Higher (Gross) 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%

American College and University President Climate Commitment

- Initially put forth in 2007 with 250 charter institutions signing the pledge for GHG neutrality by 2015
  - Interim target goals vary by institution
- Over 600 institutions have signed to date
- GHG emissions are broken into 3 categories
  - Scope 1-on campus stationery sources , central and satellite heating plants
  - Scope 2- purchased electricity
  - Scope 3- commuting, T&D losses, travel off campus, other

Typical GHG Inventory Scopes 1, 2 and 3

(University with Large Commuting Population)



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Decarbonizing District Energy (Scope 1) – Minimal Options

- Easiest options for fuel switching from coal/oil/natural gas have largely already taken place due to economics
- Conservation practices are generally into implementation, and in some instances cost money
- Fuel efficiencies can be realized with mechanical or instrumentation change outs, even CHP shift- tend to be expensive, long payouts depending on jurisdictions
- **Use of a biogenic fuel, will generally net the biggest GHG reduction with budget neutrality**
  - "conventional" biofuels typically are based on food-based feedstocks, and can be costly
  - Cellulosic biofuels offer the most attractive benefits including economics

RFO vs. Fossil Fuel LCA

Typical Comparative Analyses using GHGenius Software

GHG Emissions – Wood Feedstock

Fuel	Heating Oil	Natural Gas	PyOil (i.e., RFO)
Feedstock	Crude Oil	Natural Gas	Wood Residues
	g CO_2eq/GJ		
Fuel Dispensing	402	0	874
Fuel Distribution & Storage	698	2,063	361
Fuel Production	8,412	1,376	9,555
Feedstock Transmission	1,401	0	0
Feedstock Recovery	8,081	1,708	0
Land-use Changes, Cultivation	25	0	0
Fertilizer Manufacture	0	0	0
Gas Leaks & Flares	1,900	3,540	0
CO_2, H_2S Removed from NG	0	642	0
Emissions Displaced	-128	0	0
Sub-total Fuel Production	20,790	9,330	10,790
Fuel Combustion	68,718	51,432	301
Grand Total	89,508	60,762	11,091
% Change Compared to Heating Oil		-32.1%	-87.6%

Canadian Scenario
– Sawmill Residues
– RTP unit located at sawmill site
– Feed Transportation Distance = 0

Result: RFO 88% lower GHG than petroleum-derived heating oil and 81% lower than natural gas

LCA Result courtesy of Don O'Connor

(S&T)² Consultants Inc.
11657 Summit Crescent
Delta, BC Canada, V4E 2Z2

Typical GHG “life cycle“ GHG Factors for Combustion

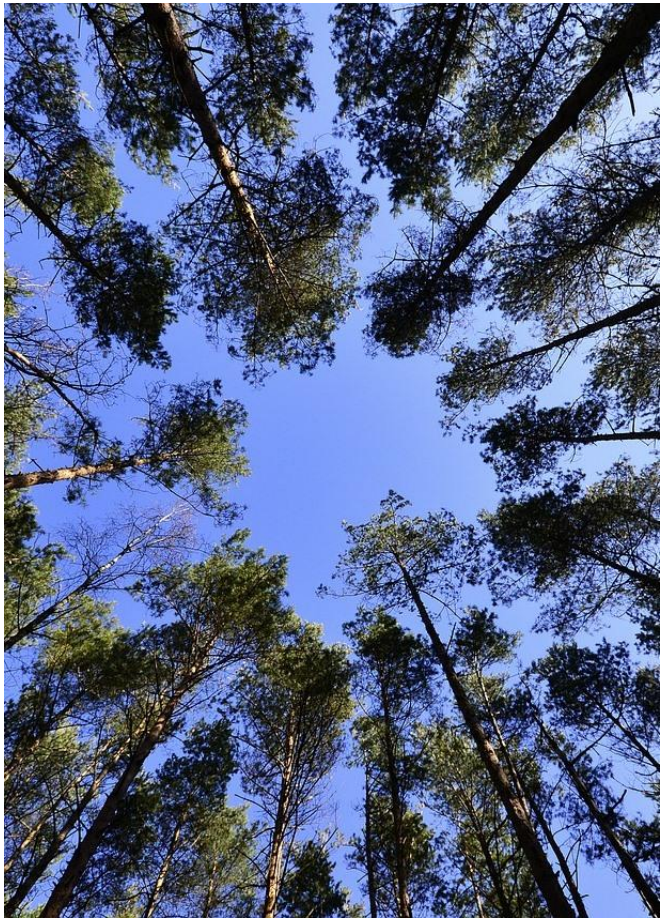
Energy Component	GHG emission factor
Oil	207 #/MMBTU
Natural Gas	141 #/MMBTU
Electricity	0.7 to 1.6 #/kwh
RFO	25.7 #/MMBTU

RTP Feedstock Requirements

- Harvest residues or commercial thinnings from a sustainably managed forest
- Harvest residues are often left in the forest or burned in the forest due to lack of markets
- Forester is required to provide an affidavit that feedstock has met approved criteria
- Each batch of fuel has a certificate that follows it which details feedstock origin
- Our feedstock suppliers are generally large forestry companies

Ensyn's Technology Produces Significant Environmental Benefits

- Ensyn's RFO is a direct substitute for fossil fuels
- Ensyn 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
- Ensyn's RFO is considered to be "biogenic' for GHG emission purposes



Price Stability and Certainty

- RFO Heating/Cooling applications has an approved pathway under RFS2 regulations to produce RINs
- In certain states, there are Thermal REC programs which apply to use of liquid fuels for heating purposes, using approved feed-stocks.
- Ensyn Fuels, a subsidiary of Ensyn, is responsible for the marketing and sales, storage, transportation and distribution of Renewable Fuel Oil

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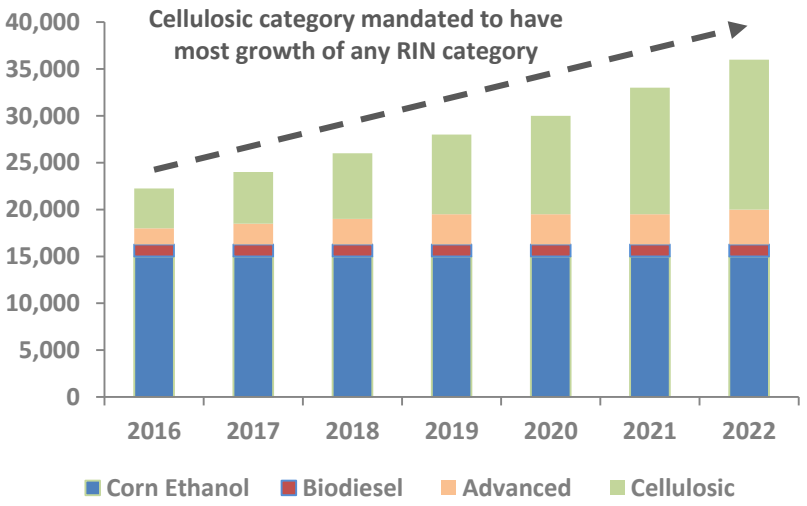
U.S. Renewable Fuel Standard (RFS)

- Enacted in 2005 and expanded in 2007
- Administered by the EPA
- Refineries are obligated parties and must integrate increasing amounts of specific types of biofuels annually
- The EPA reviews the RFS standard each year, and can adjust the mandate
- Biofuel categories are nested in terms of compliance value
- Ensyn's RFO falls under the Cellulosic RIN classification - the most valuable RIN category

RFS2 Renewable Volume Obligations (MM gal)



Source: EISA

RFS2 Biofuel Categories

	Qualifying Biofuel	GHG Threshold
Cellulosic	Any fuel derived from cellulosic biomass	60%
Biomass Based Biodiesel	FME or any hydrogenated Biodiesel	50%
Advanced	Any Fuel other than Corn Ethanol	50%
Conventional	Corn Ethanol	20%

Source: EISA

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Case Studies

- 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
- Limited boiler room labor oversight- very automated
- Over 700,000 gallons of RFO consumed to date
- Approximate GHG reduction 24,000 MT

Ensyn's RFO Easily Integrated with Existing Infrastructure

- 15,000 SS gallon 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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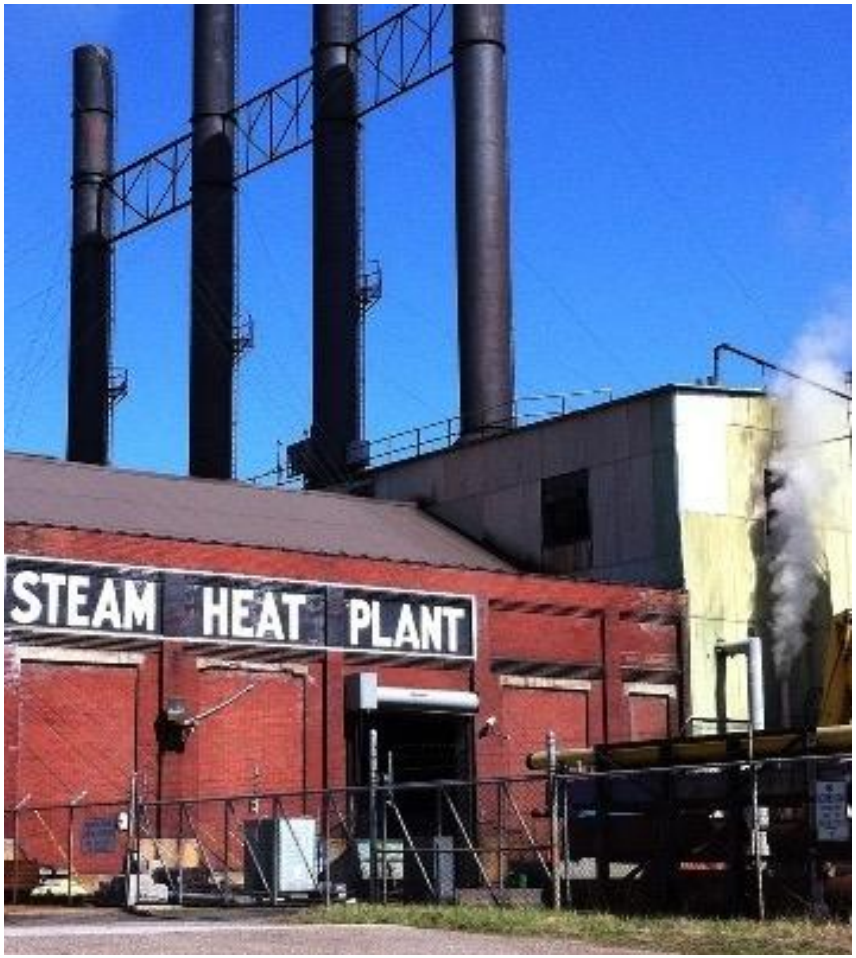
Youngstown Thermal
Youngstown, Ohio



- Youngstown Thermal is a mid-sized commercial district energy system.
- Driver was to save money, secondary impact was produce “green steam”
- Initial trial firing of RFO was early 2014
- Start up began spring of 2016
- Projected volumes of RFO use -4MG annually of RFO
- Target fuel savings being realized,
- Delay in Issuance of Title 5 permit delayed full operations till Feb 2017

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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 fit 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

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Youngstown Thermal Fuel Delivery System

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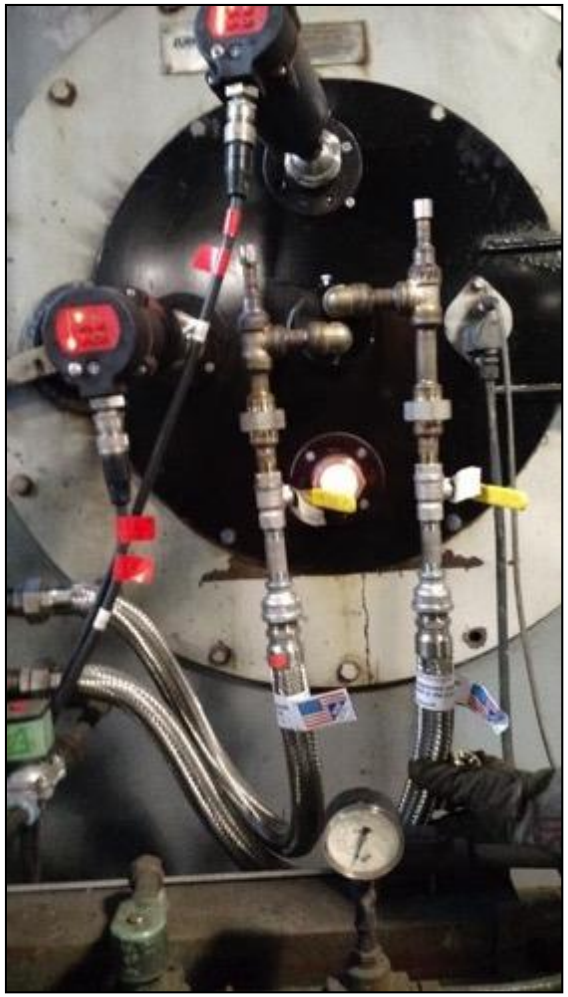
Youngstown Thermal Dual Fuel Burners



- Burner design natural gas and RFO- any combination
- 2 – each with a nominal capacity 60MMBTU/hr

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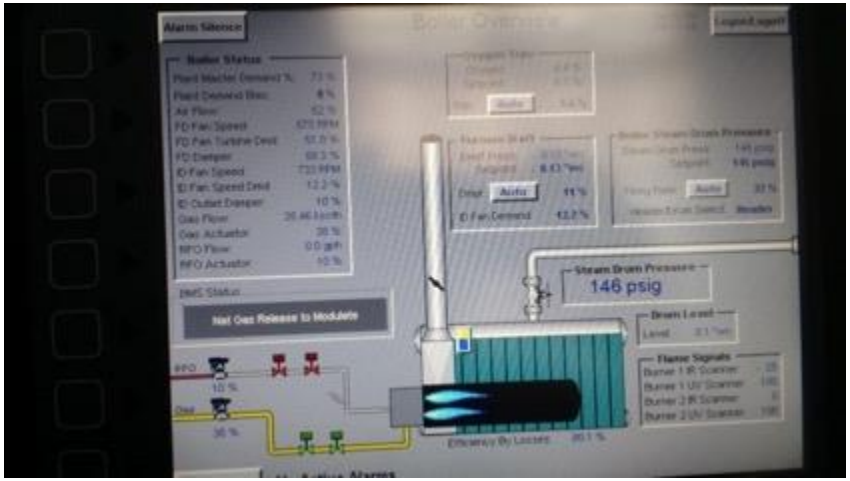
Youngstown Thermal MCC and Controls



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Youngstown Thermal RFO Fuel Guns

Bates College
Lewiston, Maine

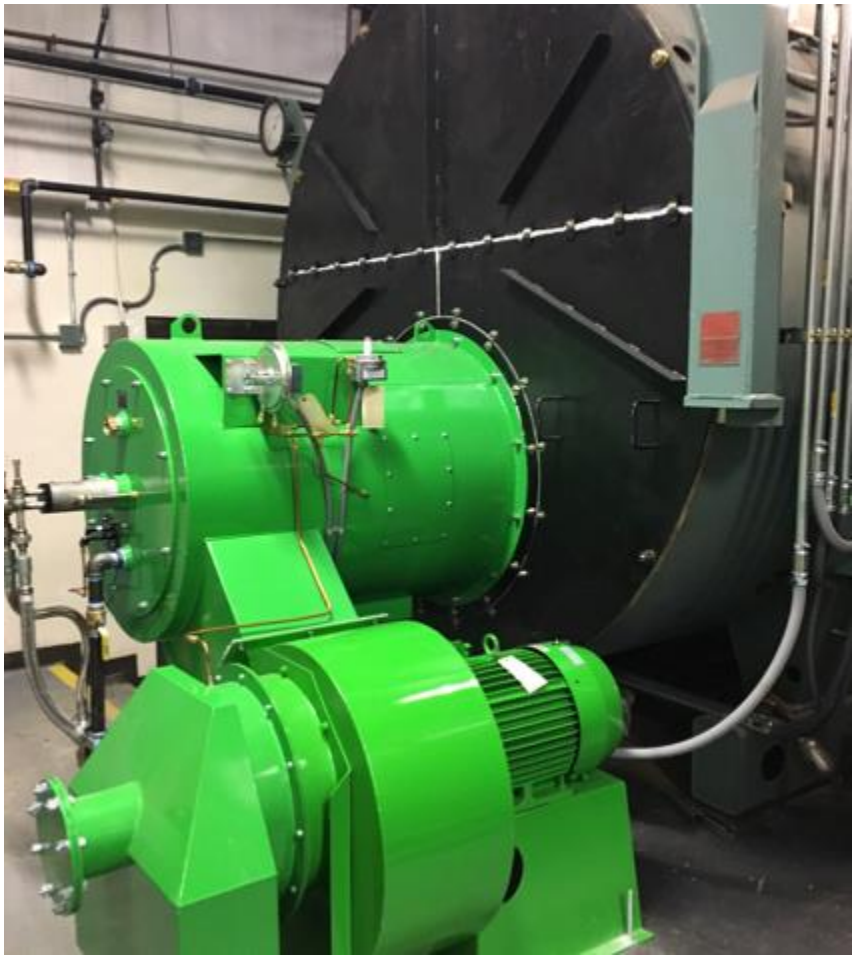
- Signed ACUPCC pledge May 16, 2007
- Pledge date for Carbon neutrality 2020
- Scope 1 GHG emissions were approximately 40% of total of Scope 1-3
- Central steam plant represents approximately 70% of the Scope 1 emissions
- Committed to initially replace ~ 70% of fuel mix at CP with RFO, added fuel redundancy

- This will result 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

Preferred Utilities 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

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