NRC Support for Accelerating Bioenergy Development in Canada

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About NRC

- Annual budget: ~$775M
- Over **4,000** employees and 650 volunteer and independent visitors
- Wide variety of disciplines and broad array of services and support to industry

NRC Program Approach & Bioenergy Value Chain

Impact	• Timely deployment (3-6 years) • Public and private ROI
Market Pull	• Engage stakeholders along the value chain: long-term commitment and trust • Co-investment ties success to industry needs
NRC Investment	• World class capabilities: national & multidisciplinary • Focus: fewer, more critical projects

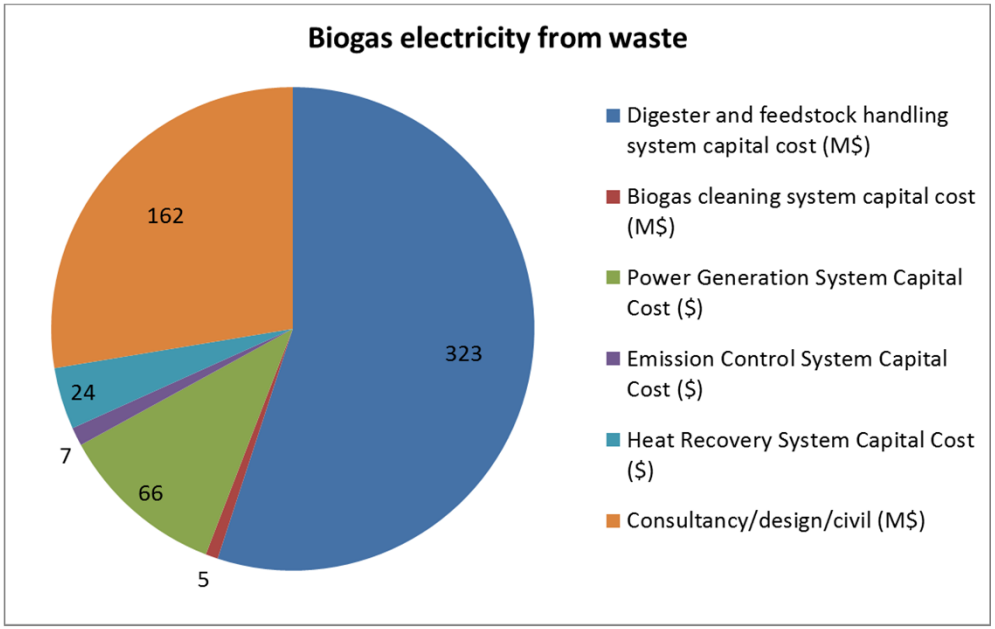
Strategically engaging the entire value chain

Enablers
- Venture capital
- Business/tech experts
- Incubators
- Regulators

Program Goals

To make bioenergy technology platforms economically viable in Canadian energy markets by 2023 by:

- Strengthening the Canadian value chain;
- Reducing the production cost of solid and gaseous biofuels;
- Reducing the production cost of power and CHP from biofuels.



Bioenergy Program Focus

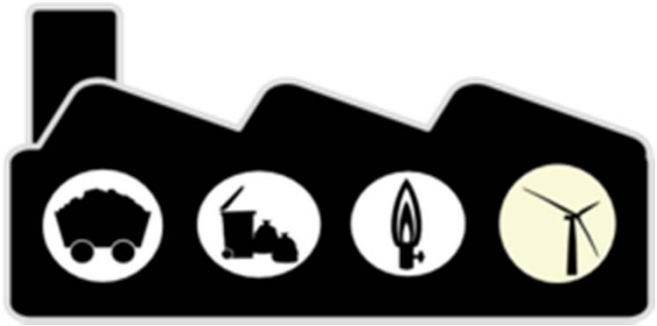
Strategic Support

Biofuel Production

Feedstock

Conversion

Upgrading



Utilization in Power Plants

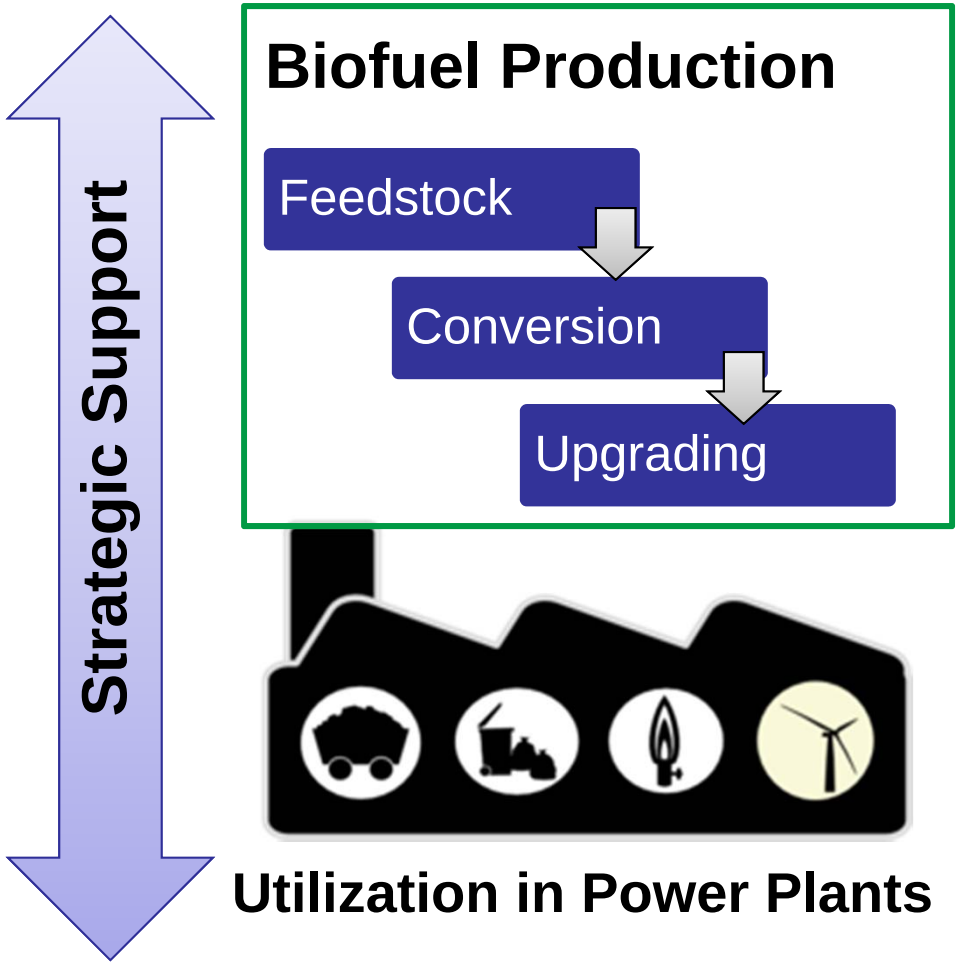
- ✓Cost
- ✓Production Efficiency
- ✓Equipment Compatibility

Remote Communities

Remote Industry

Cities with MSW

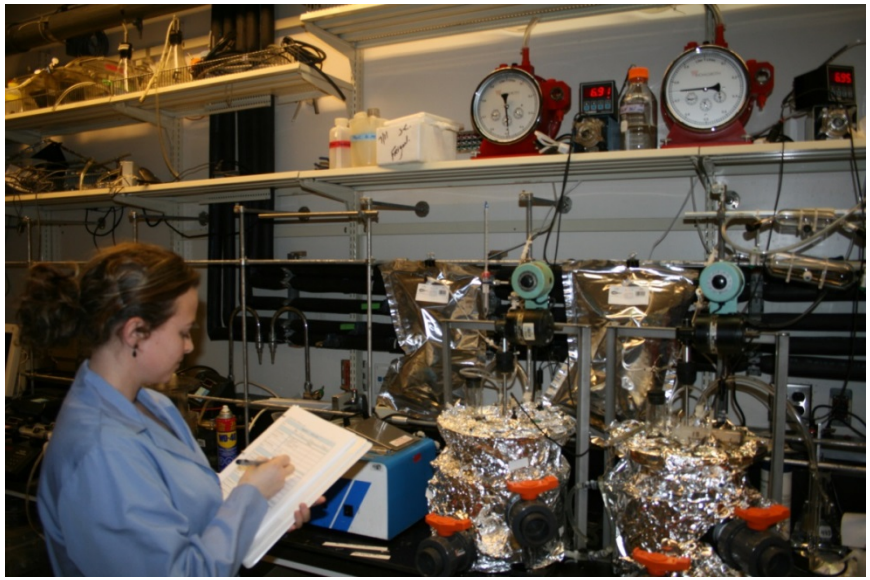
Program Activities: Biofuel Production

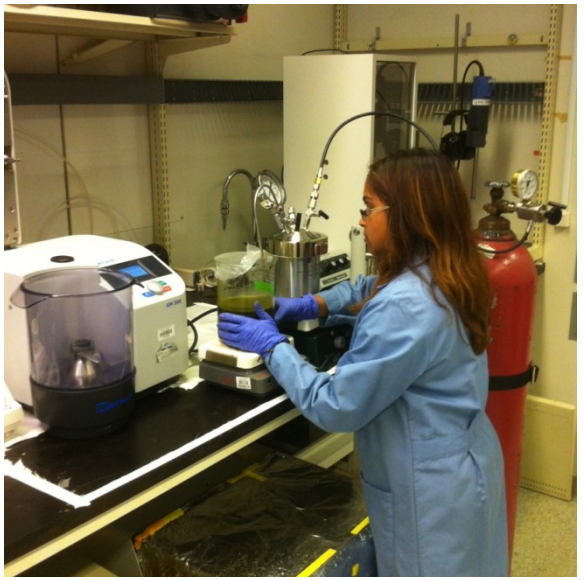


- Primary biomass conversion technologies
  - Improved efficiency/economic viability
  - Validation at pilot or demonstration scale
- Processes development for upgrading biofuels
  - Process optimization
  - Validation at pilot or demonstration scale

Sample Project: Enhanced Anaerobic Digestion

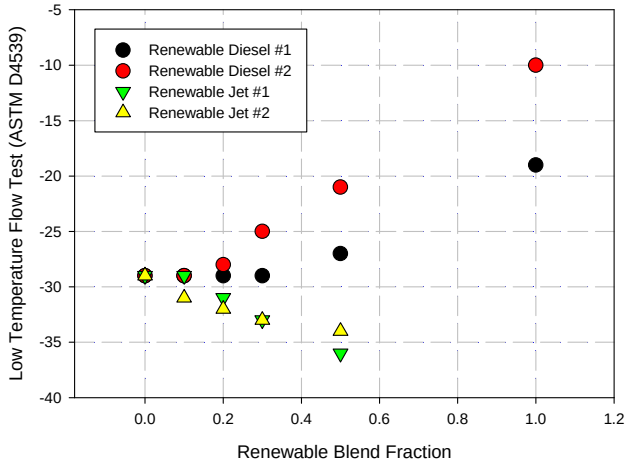
- Working with clients to identify opportunities for optimizing their systems in operation
- Using a combination of experience and novel techniques developed at NRC to increase feedstock utilization and enhance biogas production

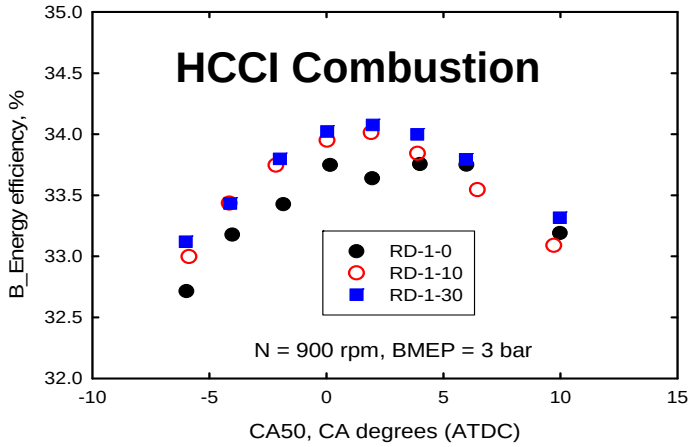




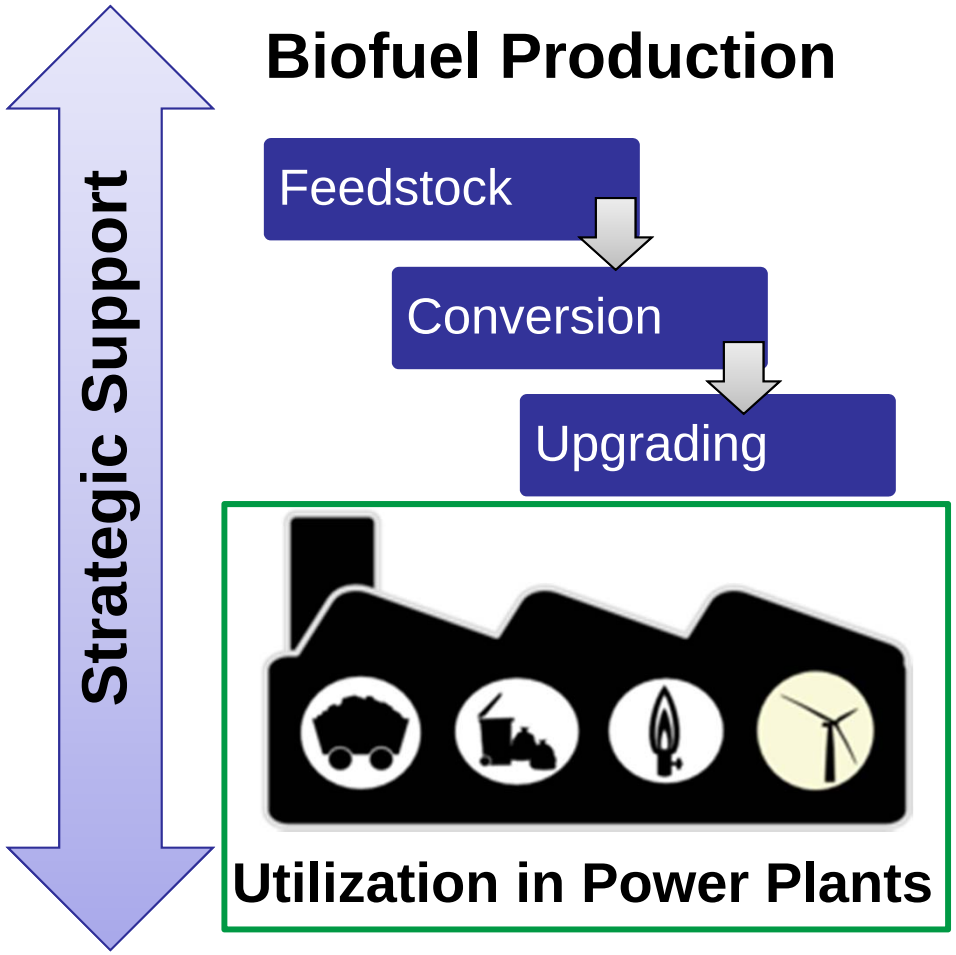
Sample Project: Renewable Fuel Blends

- NRC has participated in numerous projects to reduce the technical risks associated with introducing renewable fuels
- Effort is focused on the fit-for-service properties of renewable fuel blends and their combustion/ emissions performance
- Experience can be related to gas turbine experience.





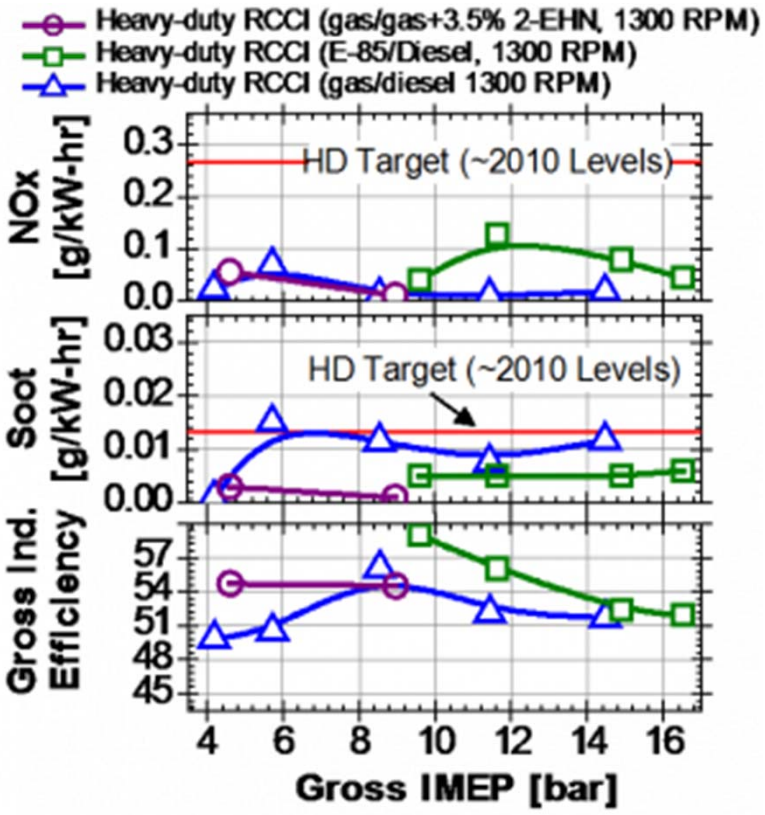
Program Activities: Utilization in Power Plants



- Addressing biofuel-power plant compatibility issues
  - Engine and component R&D for fuel-flexibility
- Lowering capex and opex for bioenergy power systems
  - Advance low-TRL research
  - Engage with component suppliers to develop market opportunities

Sample Project: Dual-Fuel Combustion

- Fuel-flexible retrofit solutions for power plants are attractive for reduced diesel fuel consumption in remote communities
- Adaption of advanced combustion strategies being developed for the automotive market
- Multi-year projects sponsored by federal funding with industry engagement
- Opportunity to engage in similar work for GTs



Courtesy of WERC

Program Activities: Strategic Support and Analysis

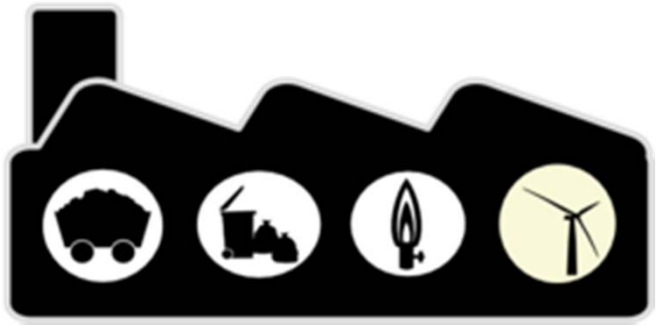
Strategic Support

Biofuel Production

Feedstock

Conversion

Upgrading



Utilization in Power Plants

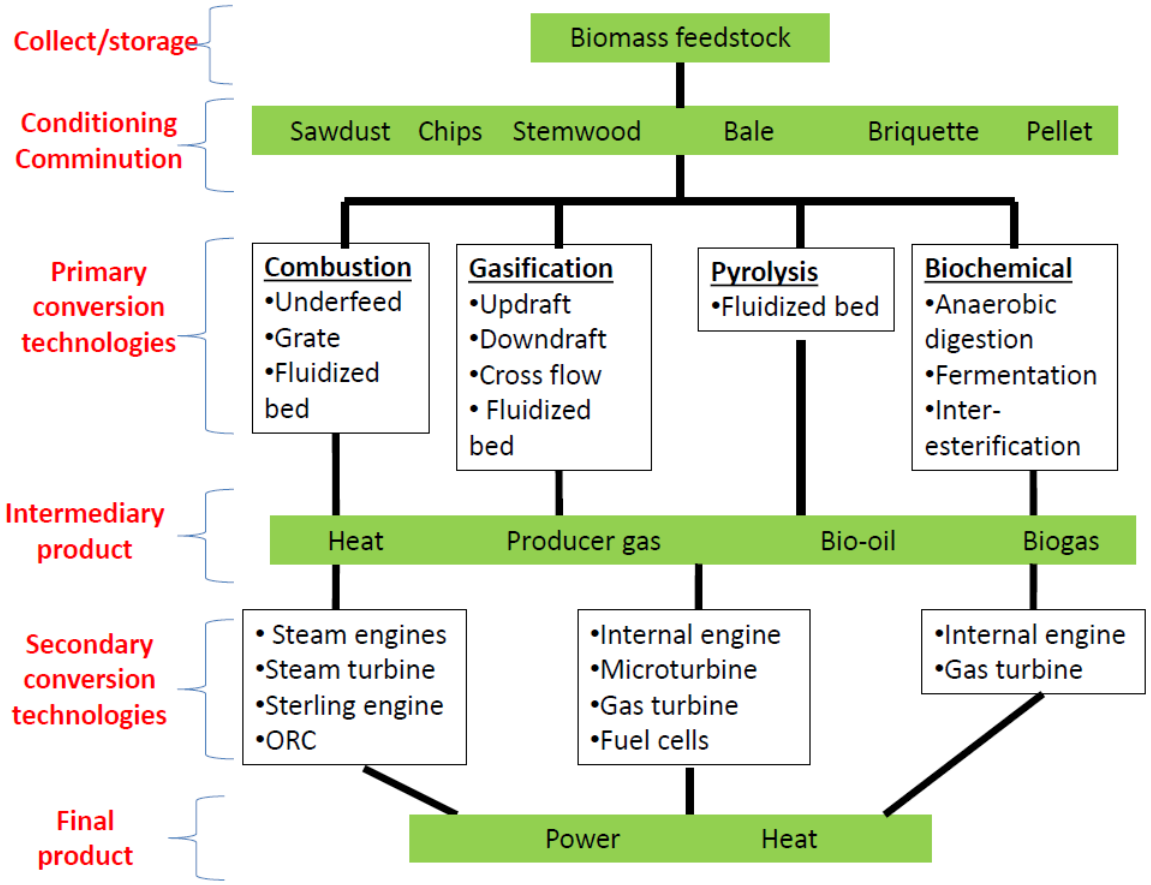
- Technical support for codes and standards
  - External partnerships to address integration & regulatory issues
  - Develop quality analysis tools/techniques
- Techno-economic analysis
  - KPIs and statistics for demonstration projects
  - Support for technology demonstrations
  - Coordinate efforts with external agencies

Sample Project: Safety Codes and Standards

- Client is developing waste-to-energy technology, several units in operation
- Trying to expand markets, but C&S don't exist to cover pyrolysis and gasification appliances.
- Needing evaluation of C&S landscape and roadmap for compliance

Work Task Description
Task 1: Conduct preliminary analysis of client's technology
Task 2: Source and procure safety C&S documents identified
Task 3: Conduct detailed analysis of safety C&S documents including a gap analysis
Task 4: Perform detailed evaluation of the client's system for compliance with current safety C&S
Task 5: Generate a roadmap to facilitate appliance certification for safety

Sample Projects: Bioenergy Market Assessment Tool



Sample outputs for 5MW System

Expenses--base year		($/kWh)
Fuel Cost ($/t)	22.05	0.0213
Labor Cost ($/y)	1,000,000	0.0269
Maintenance Cost ($/y)	500,000	0.0134
Insurance/Property Tax ($/y)	400,000	0.0107
Utilities ($/y)	60,000	0.0016
Ash Disposal ($/y)--use negative value for sales	30,000	0.0008
Management/Administration ($/y)	60,000	0.0016
Other Operating Expenses ($/y)	100,000	0.0027
Total Non-Fuel Expenses ($/y)	2,150,000	0.0577
Total Expenses Including Fuel ($/y)	2,944,099	0.0791

Biggest challenge: Lack of field data particularly in remote communities

OPPORTUNITIES FOR COLLABORATION WITH THE BIOENERGY PROGRAM

Challenges of using Biofuels in Gas Turbines

For gaseous fuels (syngas):

- Reliable and cost-effective syngas cleanup and conditioning to enable commercial deployment.
- Understanding the compositional effects on combustor operability (flashback, flameout, instabilities), as well on liner life and engine pattern factor influences.
- Turbomachinery flexibility & operability.

For liquid fuels (e.g. pyrolysis oils):

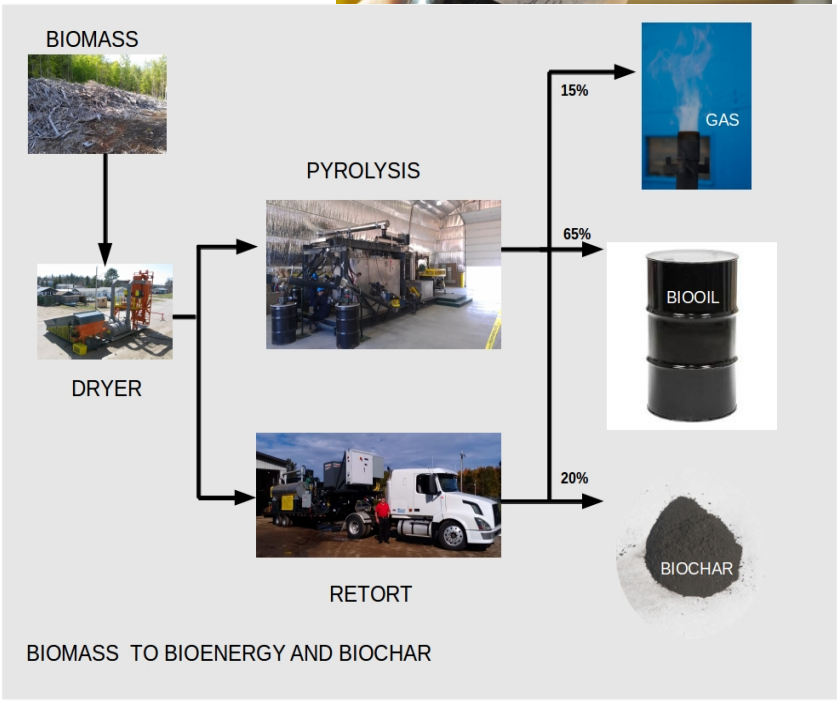
- Atomization and combustion
- Thermal stabilities and coking mechanism of oxygen-containing, low-BTU fuels.

In general:

- Corrosion-resistant, and high-temperature materials and coatings.
- Engine durability and endurance.

Use of Pyrolysis Oil in Gas Turbines (2014 –) 1 of 3

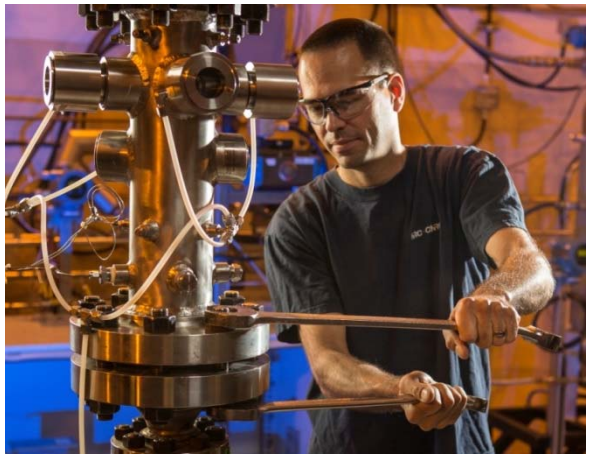
- Working with Canadian bio-oil producers such as pyrolysis oil, bioethanol, etc.
- NRC's effort in the areas of:
  - Characterization of physical and chemical fuel properties
  - Improving the fuel qualities through process change, blending with other fuels
  - Performance evaluation in spray and combustion facility

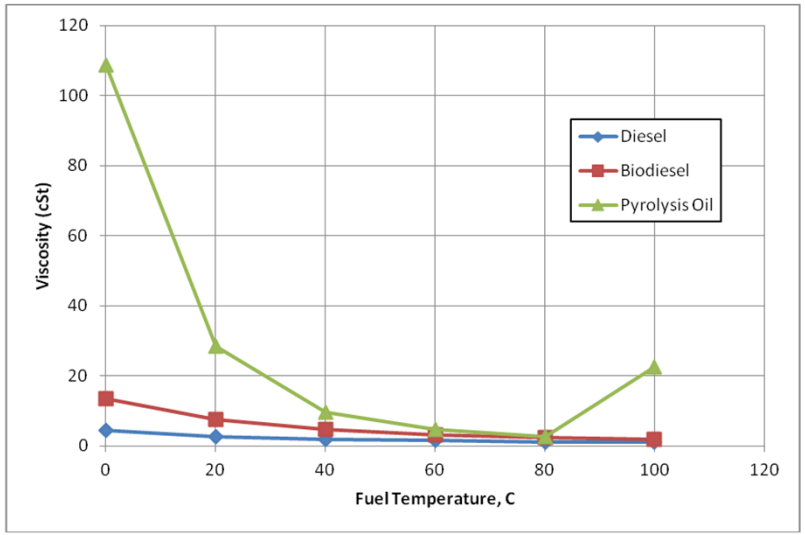


Picture from www.arbitechinc.com

Use of Pyrolysis Oil in Gas Turbines(2014 –) 2 of 3

- Extremely high viscosity compared other fuels
- Viscosity decreases as fuel temperature rises
- Upper temperature limit exists due to polymerization
- Conduct spray testing and evaluate spray characteristics





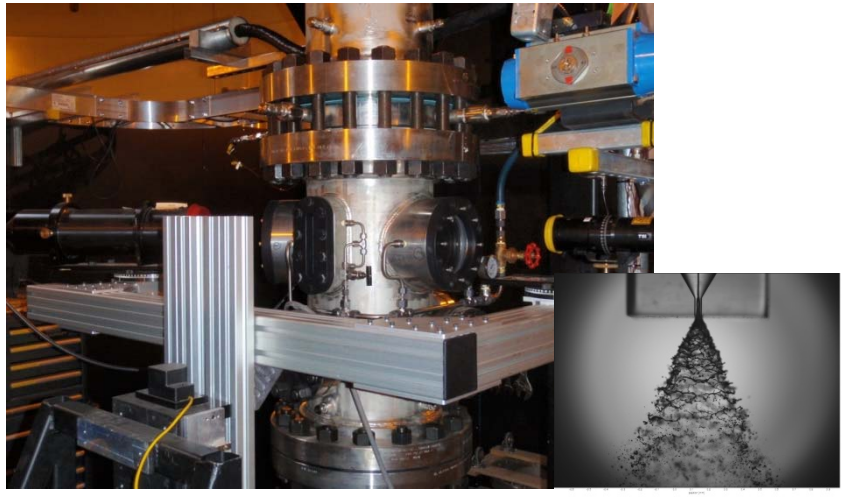
Use of Pyrolysis Oil in Gas Turbines(2014 –) 3 of 3

Facility Specification:

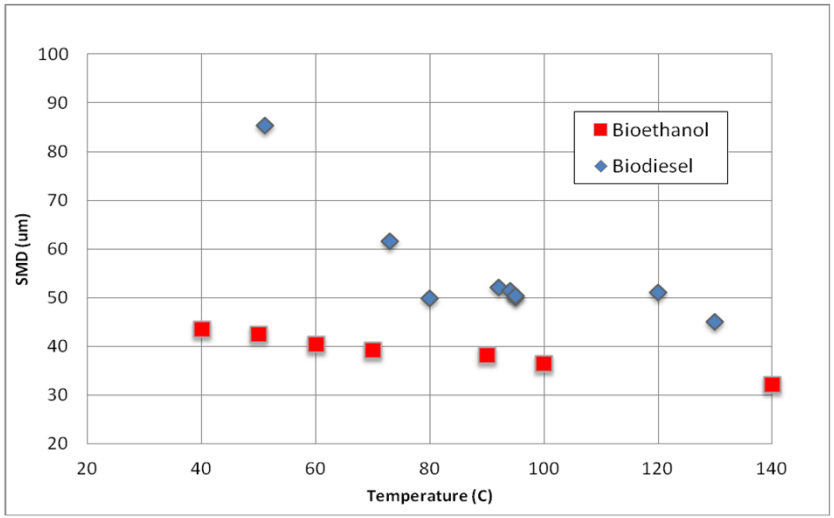
- Spray testing at high pressure conditions
- 4 Ways Optical Accessibility
- Air Box enclosing fuel injector w/t swirler
- Compressed air or nitrogen can be supplied

Measurement:

- Temperature, pressure, mass flow rates
- Laser based diagnostics:
  - Phase Doppler Particle Analyzer (PDPA)
  - Particle Image Velocimetry (PIV)
  - Malvern Laser Diffraction Particle Size Analyzer



	Press.(psia)	Temp.(K)	Flow Rate (lb/sec)
Air	25 ~ 120	Ambient	0.01 ~ 0.3
Fuel	30 ~ 550	Ambient ~ 600	5 ~150 (lb/hr)



Mircroturbine Demonstration (2016 –)

- Integration of a microturbine with a biomass gasifier
- Operational envelope testing for a wide range of electrical, mechanical and heat demands
- Material durability analysis
- Environmental impact analysis

- Ingersoll Rand IR70 micro turbine
- 70kW, low emission GT, Generator, Recuperator

- Optimizable for various feedstocks
- Producer gas composition (H2, CO2, CO, CH4)
- Continuous composition, tar, ash, contaminant monitoring

Sensors for Prognostics and Health Management

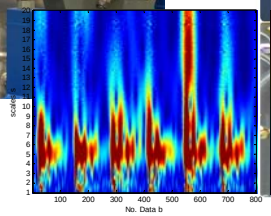
- NRC has worked for many years researching the field of health management for aero-propulsion systems

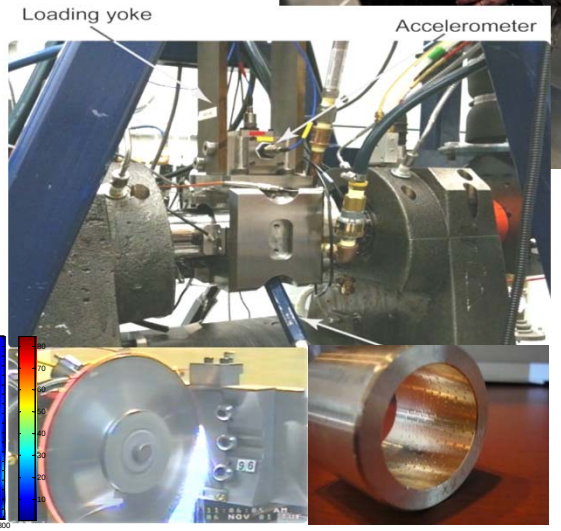
- Opportunity to leverage expertise and capabilities for stationary applications.

- Examples of sensors developed in-house:
  - Engine oil condition monitoring sensor [TRL5]
  - Particle detection system sensor [TRL5]
  - Ultrasonic fuel/engine oil leak detection sensor [TRL4]
  - Bearing condition monitoring sensor [TRL3]
  - Optical method for bearing skidding measurements [TRL3]
  - Engine vibration monitoring sensor at elevated operating temperature [TRL2]

Other Areas

- Turbomachinery Research
- Materials and Coatings
- Mechanical Components and Tribology
- Manufacturing
- Combustor Testing and Development
- Engine Performance and Operability





Thank you.

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