Alberta Biochar Initiative
and
North American Biochar Working Group

Don Harfield, P.Eng., P.M.P
Thermochemical Processing Team Lead
Vegreville, Alberta, Canada

Presentation to USBI 2016
Corvallis, Oregon, August 23, 2016
Presentation Outline

- Alberta Innovates
- Thermochemical Processing Expertise
- AITF Biochar Research
- Alberta Biochar Initiative
- NA Biochar Working Group
Alberta Innovates Family

Focuses on strategic Alberta economic sectors:

- **Energy**: Oil sands, oil and gas, pipelines, tight oil and fracking
- **Carbon** Conversion, Capture and Storage
- **Environmental** Monitoring and Management
- **Sustainable Resources**: Agriculture and Forestry
- **Industrial Sensors**
- **Advanced Materials** and Manufacturing
- **Health Research** and Technologies
AITF was established on January 1, 2010, when four organizations merged (Alberta Ingenuity, Alberta Research Council, iCORE and nanoAlberta).

AITF will become a new wholly owned subsidiary of Alberta Innovates when consolidation of all Alberta Innovates occurs on or about October 1.

AITF will have a new name to reflect the enhanced role in specialized applied research services.
AITF – Current Mandate and Role

- Economic and Social Benefits of Albertans (ESBA)
- Research and Innovation Activities that develop and grow the technology based sector aligned to GoA priorities, including the commercialization of technology and the application of knowledge
- Meet Alberta’s Research and Innovation Priorities in agriculture, forestry, energy, the environment, health and other sector areas
- Foster Development and Growth of new and existing industries through research and innovation
Edmonton
(C-Fer Technologies)

Edmonton
(Millwoods)

Devon

Vegreville

Calgary

- 520 world class scientists, engineers, technicians, and business experts
- 1 million sq ft of bench, pilot-scale and demonstration facilities
- 1000+ industry clients per year
- 90+ years of operation
- $ 75 M fee for service
AITF Thermochemical Expertise

- **Vegreville Location**
  - Don Harfield, P. Eng., P.M.P., Team Lead
  - Ataullah Khan, Ph.D., Pyrolysis, Activated Carbon & Catalyst Research Specialist
  - Jin Tak, P. Eng, Combustion and Chemical Engineer
  - Tim Anderson, Operations & Lab Supervisor
  - Ami Tymchak, Alternative Energy Technologist

- **Millwoods Location**
  - Robert Wray, P. Eng., Wood Fibre & Torrefaction Specialist
  - Stephanie Trottier, P. Eng, Gasification Specialist
  - Laura McIlveen, P.Eng., Forestry Technical Specialist

- **ABI Collaboration Partner, Lakeland College**
  - Diane Harms, Executive Director, Vermilion
AITF Thermochemical Expertise

- **Biochar Production, Slow Pyrolysis**
  - Lab, Bench, Pilot and Demonstration Scale Facilities
  - Biochar Production & Quality Assurance
  - Alberta Biochar Initiative (ABI) Founder

- **Activated Carbons & Functionalized Biochars**

- **Torrefaction**
  - Torrefied Wood Production & Quality Assurance
  - Torrefied Wood Pellets & Binders

- **Wood Combustion**
  - Lab & Pilot Scale Combustion Testing Facilities
  - Demonstration Scale Facilities (Strathcona, Camrose)
  - Client Evaluations (i.e. CHP with Organic Rankine Cycle)
Related Technical Expertise

- **Gasification**
  - Community Power 35kw Demo Scale Facility

- **Hydrothermal Carbonization**
  - Wet Bio-Coal Conversion
  - Municipal Applications for Wet Biomass or Pathogens

- **Slow Release Fertilizers**

- **Carbon Carrier for Specialty Ag Formulations**

- **Recent Feasibility Studies**
  - Sawmill CHP (Gasification, ORC – 3 MW)
  - Municipal Solid Waste Strategies
  - Biomass Products (Animal Bedding)

- **Performance Validation & Emissions Testing**

- **Process Design & 3rd Party Evaluations**
Particle Engineering Applications to Increased Use of Biomass By-Products

Richard L. Johnson, Carolyn Sturgess and Albert J. Liem
Alberta Research Council, P.O. Bag 4000, Vegreville, Alberta T9C 1T4

**Towards Industrial Ecology**

- **Value-Added Products**
- **By-Product Utilization**
- **Other applications**

- **Engineering Particles**
- **Soil Amendments**
- **Fertilizers**

**Key Technology: Feed Preparation**

- Desirable feed properties can be engineered to optimize the selected process, including minimizing air emissions. Consistent feed improves reliability and reduces operating and maintenance costs.

**Biomass as Fuel Source**

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Cost</th>
<th>Contribution to power cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>$8.5/GJ</td>
<td>~20% (electrical); ~75%</td>
</tr>
<tr>
<td>Coal</td>
<td>80–850 C</td>
<td>9.1 12.5 20%</td>
</tr>
<tr>
<td>Biomass</td>
<td>85–100 C</td>
<td>9.5 0.9 20%</td>
</tr>
</tbody>
</table>

**Economical**

- Low Life-Cycle Greenhouse Gas
  - Use of biomass results in lower carbon emissions compared to fossil fuels.

**WANTED: Feasibility, R&D or Demonstration Projects**

Contact: Richard L. Johnson, (780) 632 8252, richardj@arc.ab.ca

High Variability in Reported Cost Data
- Capital Cost: 1,300 - 25,000 $/kW
- Energy Generation Cost: 0 - 45 c/kW-h
- Evaluation should be made based on plant size, fuel cost, needs and other site-specific conditions

**General Overview**

- Technology: Not economical for small size
- Efficiencies ~ 25%
- Suitable for small-scale, "omnivorous", low maintenance
- Early demonstration stage
- ~ 20% (electrical); ~ 75% improvements expected
- Demonstrated for medium and large-scale
- More complex; small-scale in early demonstration stage
- ~ 70% (electrical); ~ 75%
- Suitable technology (fossil fuel)
- Biomass applications not as well developed; maintenance
- ~ 50% (electrical); ~ 75%
- Small-scale (fossil fuel) demonstrated
- Biomass applications not as well developed
- ~ 25% (electrical); ~ 75%
- More complex; small-scale in early demonstration stage
- ~ 20% (electrical); ~ 60%; improvements expected
- Production of gaseous, liquid and solid products as feed stocks or for fuels
- Simplified processes

**Substitution of coal with biomass. Up to 15% has been achieved.**

- Minimum capital cost

**Independent Evaluation of Options* for Energy Generation**

- **Natural Gas**
- **Biomass**
- **Coal**
- **Combined Heat & Power**
Background Research Into Biochar

- 2001 – Particle Engineering Group Established
  - R. L. Johnson (Soils Scientist)
- 2003 – Expertise Developed
  - Direct Fired Combustion
  - Gasification
  - Pyrolysis for Fuels and Bio-Coal
  - Co-Firing Substitution of Wood and Bio-Coal
- 2004 – Activated Carbons, MSW Pellet Gasification
- 2005 – Chemically Activated Carbon (Acid)
- 2006 – Steam Activated Carbons (4” Tube Furnace)
Background Research Into Biochar

- 2007 – Biomass Combustion (Ag Residues & Wood)
- 2008 – Batch Carbonizer & Biochar Products
- 2009 – Biochar Product Development (“Carbon Grow”)
- 2010 – Demonstration Biomass Combustion Facility
- 2011 – Alberta Biochar Initiative (ABI) Commenced
- 2012 – Demonstration Scale Biochar Units Built
- 2013 – Hydroponic Greenhouse Biochar Trials
- 2014 – Oil Sands Tailings Extraction (Funct. Biochar)
- 2015 – ABI Successful Results, Bio-Oils/Phenol Glues, CFIA Biochar Approval
AITF Bench Scale Pyrolysis System
Specialty Biochars
AITF Pilot Scale – Product Development
Specialty Chars & Pyrolysis Oils

AITF Continuous Pyrolyzer
AITF Pilot Scale – Product Development
Batch Carbonizer and Steam Activation

AITF Batch Carbonizer
Co-founder of the Alberta Biochar Initiative
Two ABI demonstration scale pyrolysis units located in Vegreville (commissioned in 2013)
Produced and analyzed a wide variety of biochars produced from varying feedstock materials and pyrolysis conditions
Analytical lab & established quality standards
Alberta Biochar Initiative (ABI)

Theme 1
- Mobile Pyrolytic Units
- Biochar production
- Biochar standards
- Biochar quality testing
- Biochar end-use demos

Theme 2
Biochar Growth Media (greenhouse crops)

Theme 3
Biochar for Reclamation/remediation (Target Oil & Gas Sector)

Theme 4
Biochar soil amendments to boost crop yield

Theme 5
Biochar Network and partnership engagement

Theme 6
Biochar LCA (as a tool for carbon sequestration)
Alberta Biochar Initiative (ABI)

- 2011 Prior Biochar Study – Market Opportunities
- Pre-Commercial Demonstration Project (3 Yr)
- Initially Federally Funded by WD – $ 900k
- Partners: AITF, Lakeland College, Industry
- Two Mobile Demo Units (0.5 tonne/day biochar output)
- Carbon Sequestration and GHG Mitigation
- Biochar Network & Partnership Engagement
- Successfully Concluded Funding Period June 2015
- Continuing With Partners to Commercialize Biochar
ABI Theme 1 – Mobile Production

- Acquired & Commissioned Two Pyrolysis Units
- Hired New Scientist to Lead Pyrolysis
- 7 Feedstock Characterization & Quality Evaluations
- Biochar Hydroponic Media Product Safety
- Demonstration Workshops
- Regulatory Application Process Development
ABI Theme 2 – Biochar Growth Media

- Produce Biochar from Pulp Mill Sludge
  - Replacement for Perlite & Vermiculite
- Commercial Greenhouse Testing
  - CDC South, Kwantlen
- Microbial Analyses of Biochar & Coir
- Disease Suppression Trials
- Food Safety Testing
- Guidelines for Greenhouse Operators
ABI Theme 3 – Land Reclamation

- Develop Biochar Based Soil Amendment
- Field Trials for Land Reclamation
  - AITF, Peace River
- Activation of Biochar and Adsorbent Testing
  - Removal of Organic Carbon Extraction from OSTP)
ABI Theme 4 – Improved Crop Yields

- Production of Biochar from Jerusalem Artichoke, Wheat Straw, Coppice Willow
- Field Trials at Lakeland College (4 Years)
- Evaluate Ameliorative Potential on Soloneztic Soils
Engagement with 55 Entrepreneurs & Institutions
  Since Increased to 65 Partners
10 Workshops Demonstrating Biochar Units
Deployment of Biochar Units Offsite
37 Technical, Education & Networking Events
  Edmonton Telus World of Science (Jr. & High School)
Operational Training of Personnel
Assisted Partners in Regulatory Applications
  2 AENV Code of Practice for Biochar Production
  3 CFIA Applications for Biochar as Soil Amendment
ABI Theme 6 – Carbon Sequestration

- Developed Offset Protocols to Guide Regulations
- Consulted With Alberta Environment and CCEMC
- Issued Report to Develop Alberta GHG Offset System
CFIA Approval – Biochar!!!

- CFIA considers ‘Biochar’ as a supplement under the Federal Fertilizer Act and requires specific registration prior to sale/import or prior to environmental release in Canada.
- **Air Terra** with AITF assistance pioneered Biochar Registration with CFIA in Canada
- **Air Terra Biochar** approved December 2015
- CFIA non-compliance could result in product detention and prosecution.
- AITF assisting with other CFIA applications
## Air Terra Biochar - Specifications

<table>
<thead>
<tr>
<th>Biochar</th>
<th>Average Result</th>
<th>Air Terra Product Min. Guarantee</th>
<th>Max. Allowable Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximate Analyses wt.% dry basis (db)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>8.5 %</td>
<td>≤ 25 %</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>6.7 %</td>
<td>≥ 70 %</td>
<td>IBI Class 1 (&gt; 60 %)*</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>84.8 %</td>
<td>≥ 70 %</td>
<td></td>
</tr>
</tbody>
</table>

### Ultimate Analyses wt.% (db)

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>84.56 %</td>
</tr>
<tr>
<td>H</td>
<td>0.68 %</td>
</tr>
<tr>
<td>O</td>
<td>7.84 %</td>
</tr>
<tr>
<td>N</td>
<td>0.22 %</td>
</tr>
<tr>
<td>S</td>
<td>0</td>
</tr>
</tbody>
</table>

### Atomic Ratios

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Value</th>
<th>IBI guidelines* requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>H/C</td>
<td>0.1</td>
<td>H/C&lt;sub&gt;org&lt;/sub&gt; ratio ≤ 0.7</td>
</tr>
<tr>
<td>O/C</td>
<td>0.07</td>
<td>Biochar with O/C atomic ratio &lt; 0.2, have an estimated half-life (T&lt;sub&gt;1/2&lt;/sub&gt;) &gt; 1000 year [Carbon Management 2010, 1, 289]</td>
</tr>
</tbody>
</table>

### Toxicity Bio-Assay

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germination Rate</td>
<td>100 %</td>
<td>Radish seed germination rate in biochar relative to quartz sand control</td>
</tr>
</tbody>
</table>

### Toxicants

<table>
<thead>
<tr>
<th>Toxicant</th>
<th>Result</th>
<th>IBI guideline* requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polycyclic Hydrocarbons - PAHs</td>
<td>1.6 mg/kg</td>
<td>&lt; 20 mg/kg IBI guideline*</td>
</tr>
<tr>
<td>Dioxins</td>
<td>Not detected</td>
<td>&lt; 9 ng/kg IBI guideline*</td>
</tr>
<tr>
<td>Furans</td>
<td>Not detected</td>
<td>&lt; 9 ng/kg IBI guideline*</td>
</tr>
<tr>
<td>Poly Chlorinated Biphenyls - PCBs</td>
<td>Not detected</td>
<td>&lt; 0.5 mg/kg IBI guideline*</td>
</tr>
<tr>
<td>Heavy Metals</td>
<td>Within max. allowable conc.</td>
<td>Below CFIA T-4-093 standard threshold</td>
</tr>
</tbody>
</table>
## Biochar: Chicken Soup for the Soil!

<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>BIOCHAR</th>
<th>CHICKEN SOUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improves Health</td>
<td>Improves soil compaction, oxygenation, fertility, water and nutrient retention. Improves soil immunity to disease.</td>
<td>Improves heart health, breathing, digestion, restores immunity, better intestinal flow and spring in your step!</td>
</tr>
<tr>
<td>Increases Productivity</td>
<td>Reduces soil erosion and improves crop production from marginal or damaged soils.</td>
<td>Helps restore health and return person to work (and family) sooner and more effectively.</td>
</tr>
<tr>
<td>Reduces Need for Chemicals</td>
<td>Reduces need for chemical fertilizers and reduced leaching of nitrogen and phosphorous.</td>
<td>Reduces need for pharmaceuticals and cold (and other) medications</td>
</tr>
<tr>
<td>Improves Symbiotic Alignment</td>
<td>Provides high surface area and porous network for microbial growth and enzymes for plant root system.</td>
<td>Re-establishes intestinal microbial balance and harmony for mind and body.</td>
</tr>
<tr>
<td>Greenhouse Gas Mitigation</td>
<td>Reduces nitrous oxide emissions by 50 to 80% and methane suppression.</td>
<td>Restabilizes intestinal balance, reduces gas bloating, and noxious emissions</td>
</tr>
<tr>
<td>Lasts a Long Time</td>
<td>Recalcitrant stability (longevity) in soil (i.e. Terra Preta).</td>
<td>Helps you live longer and gives you zest for life.</td>
</tr>
<tr>
<td><strong>BOTTOM LINE</strong></td>
<td><em><em>Helps restore soil, environmentally friendly, and leaves a legacy for doing good! (</em> Harfield)</em>*</td>
<td><strong>Heals body, mind, mood and soul! (Psychology Today)</strong></td>
</tr>
</tbody>
</table>
Canada’s Biomass Innovation

- **Report Issued February 2016** by CCEMC and AI Biosolutions
- **Cleantech Opportunity** for GHG reduction and Economic Prosperity
- **Canada recently signed the Paris Agreement** to reduce GHG emissions
- **Biomass can be used to reduce GHG emissions** at scales from household to heavy industry
- **Opportunities focused primarily** on biomass replacement of fossil fuels such as coal and oil at point sources
- **Draft report for Bio Cleantech in Ontario** issued in May 2016
  - Opportunities for biomass co-generation of heat & electricity
  - Displacement of coal with biomass
  - Landfill gas upgrading
  - Effective fertilizer management and modified crop practices
Biochar Technical Papers (ABI)

- Guidelines for Managing Nutrients in Greenhouse Vegetables Grown on Biochar in Alberta
- Greenhouse Trials on Biochar as the Growth Media for Cucumber, Tomato and Pepper Hydroponic Vegetable Production
- BC Pre-commercial Demonstration of Three Greenhouse Vegetable Crops Grown in Biochar Media Compared with Industry Standard Coco Coir Media
- *A Fusarium Oxysporum* Disease Challenge on a Greenhouse Mini-Cucumber Crop to Compare Disease Suppression Effects of Biochar as a Growth Medium with Coco
Biochar Technical Papers (ABI)

- Mapping Biochar Characteristics for Greenhouse Produce Safety Demonstration
- Performance & Emissions Testing ABI Biochar Production Units
- Greenhouse Trials on the Impacts of Biochar on Plant Pathogen Development and on Diseases Incidences in Greenhouse Cucumber and Tomato Plants
- Intent to Develop Alberta Biochar GHG Offset System
Transform biochar (carbonized biomass) to high value activated carbon replacements

<table>
<thead>
<tr>
<th></th>
<th>Biochar</th>
<th>Activated Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Price (d.b.)</td>
<td>$100 to 500 USD</td>
<td>$1,500 to 5,000 + USD</td>
</tr>
<tr>
<td>Product Quality</td>
<td>Standards Being Developed</td>
<td>Well Defined</td>
</tr>
<tr>
<td>Market Applications</td>
<td>Being Established, Field Trials</td>
<td>Well Established</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>Intensive, Scale Dependent</td>
<td>Intensive, Scale Dependent</td>
</tr>
</tbody>
</table>
Activated Carbon Market Overview

- Global AC market valued at $1.9B in 2012 and expected to reach $4.2B by 2019
- Large number of potential applications
  - Mercury capture is a major driver for market growth due to new regulations
  - Other potential applications: Flue gas desulfurization, metal removal/recovery, LFG cleanup, capacitive deionization
- Competitive landscape
  - 50% market share held by top 3 companies: Cabot Norit, Calgon Carbon, and Evoqua (Siemens)
  - Powdered activated carbon; particle size 1-150 μm
  - Granular activated carbon; particle size 0.5-4 mm
  - Extruded activated carbon; particle size 0.8-4 mm
Example – Mercury Removal

Mercury Removal from Flue Gas Streams:

Powdered Activated Carbon injection is currently recognized as the “Best Available Control Technology (BACT)” by the EPA for mercury removal in flue gas.
AITF Functionalized Biochar (FBC)

### Hg Capture Performance

<table>
<thead>
<tr>
<th>Sorbent</th>
<th>Hg Capture Capacity %</th>
</tr>
</thead>
<tbody>
<tr>
<td>AITF-FBC</td>
<td>98.7*</td>
</tr>
<tr>
<td>Darco Hg-LH</td>
<td>94.7*</td>
</tr>
</tbody>
</table>

*Equilibrium Temperature $T_{eq} = 22^\circ C$; Ar Carrier: 200μL injection; 15.6 pg/μL;  
*Equilibrium Temperature $T_{eq} = 22^\circ C$; Flue Gas Carrier: 500μL injection; 15.6 pg/μL;  
Flue Gas Composition: O2: 5%; NO2: 300 ppm; SO2: 350 ppm; N2: Balance;  

### Surface Area Measurements

<table>
<thead>
<tr>
<th>Sorbent</th>
<th>BET SA* m²/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>AITF-FBC</td>
<td>517</td>
</tr>
<tr>
<td>Darco Hg</td>
<td>660</td>
</tr>
<tr>
<td>Darco Hg-LH</td>
<td>335</td>
</tr>
</tbody>
</table>

*N₂ physisorption

### Abrasion Number Measurement

<table>
<thead>
<tr>
<th>Sorbent</th>
<th>*Abrasion #</th>
</tr>
</thead>
<tbody>
<tr>
<td>AITF-FBC</td>
<td>77.2</td>
</tr>
<tr>
<td>Commercial PACs</td>
<td>70 - 92</td>
</tr>
</tbody>
</table>

*ASTM D-3802

### AITF-FBC Leachate Analyses – TCLP Testing*

<table>
<thead>
<tr>
<th>Extraction/Leaching Solution pH</th>
<th>Leachate Hg Conc. (ppb)</th>
<th>TCLP Regulated Level for Hg (D-008) in Leachate (ppb)</th>
<th>TCLP Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>21.3</td>
<td>200</td>
<td>Pass</td>
</tr>
<tr>
<td>7</td>
<td>2.02</td>
<td>200</td>
<td>Pass</td>
</tr>
<tr>
<td>11</td>
<td>3.05</td>
<td>200</td>
<td>Pass</td>
</tr>
</tbody>
</table>

*cold vapor atomic fluorescence spectrometer (CVAFS); *Spent FBC Hg conc.: 97.1 ppm;
Example: Enhanced Gold Recovery

Cyanidation:
Gold in crushed ore reacts with sodium cyanide to form a gold-cyanide complex, which is attracted to the activated carbon, allowing for easier and cheaper processing.

\[4 \text{Au} + 8(\text{NaCN}) + \text{O}_2 + \text{H}_2\text{O} = 4 \text{NaAu(CN)}_2 + 4 \text{NaOH}\]
Environmental & Other Applications

- **Toxic Organics from Oil Sands Processed Water**
  - Development of a cost-effective biochar-based adsorbent for toxic organic removal from tailings waters

- **Carbon Based Fertilizers (Slow Release)**
  - Ammonium Sulfate & Ammonium Phosphate

- **“Green” Phenolic Glues**
  - Cost savings of 40% compared to Petroleum Based Phenolic Glues
North American Biochar Working Group
North American Biochar Working Group

- **Introductory Meeting** at USBI 2016 Hosted by:
  - USBI, Alberta Biochar Initiative & Mexican Biochar Initiative
- **Purpose**: Collaboration Working Group to Advance Biochar Markets and Production in North America
- **Invitations** to all USBI 2016 Attendees
  - Representation from US, Canada & Mexico
  - Approx. 50 Attended Meeting on Monday Afternoon
- **Intended Topics Included**:
  - End User Markets and Applications
  - Production Successes and Learnings
  - Product Applications (Biochar & Activated Carbons)
  - Regulatory Considerations
North American Biochar Working Group

- **Key Discussion Points:**
  - Market Demand is the Driver to Grow Biochar Industry
  - Quality & Consistency is Paramount
  - Need for Definitions (Standards), Regulations and Policies
  - Strong Interest in Biochar Industry Association with NA Perspective
  - Strong Interest in Establishing NA Biochar Working Group

- **Outcomes**
  - Issue Survey to Working Group Attendees
  - Obtain Feedback on Priorities and Commitment for Working Group and or Industry Association
  - Develop and Issue Draft Motions for IBI and USBI
  - Obtain Input from IBI and USBI on Survey Results and Draft Motions
Opportunities to Contribute!

Benefits to Contributors!
The More You Put Into It – The Greater the Reward!

Opportunities to Contribute!

Main Contacts:

- Tom Miles – Tel (503) 292-0107
- Don Harfield – Tel (780) 632-8271
- Ramon Bacre – Tel (231) 313-5117
Thank You!

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Email: don.harfield@albertainnovates.ca

Presentation to USBI 2016
Corvallis, Oregon August 23, 2016