CLEAN RESOURCES FINAL REPORT PACKAGE

Project proponents are required to submit a Final Report Package, consisting of a Final Public Report and a Final Financial Report. These reports are to be provided under separate cover at the conclusion of projects for review and approval by Alberta Innovates (AI) Clean Resources Division. Proponents will use the two templates that follow to report key results and outcomes achieved during the project and financial details. The information requested in the templates should be considered the minimum necessary to meet AI reporting requirements; proponents are highly encouraged to include other information that may provide additional value, including more detailed appendices. Proponents must work with the AI Project Advisor during preparation of the Final Report Package to ensure submissions are of the highest possible quality and thus reduce the time and effort necessary to address issues that may emerge through the review and approval process.

Final Public Report

The Final Public Report shall outline what the project achieved and provide conclusions and recommendations for further research inquiry or technology development, together with an overview of the performance of the project in terms of process, output, outcomes and impact measures. The report must delineate all project knowledge and/or technology developed and must be in sufficient detail to permit readers to use or adapt the results for research and analysis purposes and to understand how conclusions were arrived at. It is incumbent upon the proponent to ensure that the Final Public Report **is free of any confidential information or intellectual property requiring protection**. The Final Public Report will be released by Alberta Innovates after the confidentiality period has expired as described in the Investment Agreement.

Final Financial Report

The Final Financial Report shall provide complete and accurate accounting of all project expenditures and contributions over the life of the project pertaining to Alberta Innovates, the proponent, and any project partners. The Final Financial Report will not be publicly released.

CLEAN RESOURCES FINAL PUBLIC REPORT TEMPLATE

1. PROJECT INFORMATION:

Project Title:	The All West Bio-Industrial Park: Maximizing the Value of Residual Biomass and Waste Streams for the Production of High Quality Bio-Products
Alberta Innovates Project Number:	G2018000675 (CTFS 2018-06)
Submission Date:	TBD
Total Project Cost:	$10.18 million
Alberta Innovates Funding:	$5 million
AI Project Advisor:	Mehr Nikoo

2. APPLICANT INFORMATION:

Applicant (Organization):	**All West Demolition**
Address:	6415 75 Street NW, Edmonton, AB T6E 0T3
Applicant Representative Name:	Chris Olson
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3. PROJECT PARTNERS

1. All West Demolition
2. Innovative Reduction Strategies Inc
3. Nelson Environmental Remediation
4. Octoco Inc.
5. Annelida Organics/Tidal Psychedelics
6. TrustBIX
7. Green Analytics

A. EXECUTIVE SUMMARY

The All West Bio-Industrial Park (AWBIP) involves the development and operation of an industry lead bio-industrial facility located at 6415 75 Street NW, Edmonton. The park provides space and resources for companies aimed at adding value to waste streams, with a special focus on residual biomass. The above listed site is home to All West Demolition (AWD), a prominent Edmonton based demolition company. In order to maximize the value of their waste streams, generate additional revenue and minimize their impact on the environment, AWD has brought together a consortium of technology providers, researchers and engineers to build a team in pursuit of the below listed objectives. Working with the waste streams generated by AWD the core objectives for the facility include: (1) the development of value added applications/products from waste streams through field trials leading to full commercialization, (2) the acceleration of demonstration stage technologies and processes through field trial activities, (3) access to essential engineering, software, and consulting resources for pre-commercial SME's who have viable technologies/processes applicable to this sector, and (4) working closely with research organizations and academic institutions to resolve industry challenges and train high quality personnel utilizing the Challenge Dialogue System® methodology.

This park serves as an integral part of the development of the bio-industrial sector in the Edmonton area and is leveraging the experience and expertise of industry stakeholders in a collaborative environment to expedite market entry for the park's participants in their respective sectors. A specific gap that is being addressed by the AWBIP is for field demonstration and real-world operational space for late stage technologies – both IRSI and NER occupy this space with their thermal treatment technologies and their unique process configurations. Additionally, partners added to this project scope, TrustBIX, Green Analytics, and Annelida/Tidal, are working in a space with software and products that required field demonstrations to validate their value proposition, which each has completed through this work.

Pyrolysis has been selected as a feasible solution for the thermal treatment of clean residual wood

biomass. The pyrolysis process is the heating of material in the absence of oxygen resulting in liquid, gas, and solid by-products. The liquid and gas by-products have been utilized on site as an energy source, while the solid charcoal (biochar) is a value-added product with numerous applications ranging from soil amendment to precursors for activated carbon production. The uniqueness of the activities undertaken at the AWBIP by IRSI revolves around the utilization of a modified combustion chamber to initially utilized low-grade residual biomass waste to generate initial thermal energy required to drive the indirect pyrolysis process. This sets the activities of the AWBIP apart from other comparable technologies by eliminating the need for petrochemical fuels and maximizing the ability of the site to reduce waste streams that would otherwise be landfilled. IRSI, in collaboration with research teams, have tailored specific characteristics in the biochar during the production process, which is a direct competitor to activated carbon products, and have utilized raw biochar produced from by IRSI. IRSI, along with its team, developed a lab scale activation system to process raw biochar into an activated biochar, with promising results. Future steps for IRSI at this project site will be the scaled-up fabrication of a bench scale activation system for processing larger volumes of raw biochar into activated biochar.

Industry stakeholders, through the park's advisory board, have dictated outcomes for this facility and with a focus on the successful acceleration of the bio-industrial sector and the improved management of AWD's waste streams. The facility has allowed AWD the opportunity to divert specific waste streams from landfills and towards the technologies/processes as a feedstock to create value-added products – specifically thermal treatment equipment both on site and off site for thermal and electrical energy generation. The site has provided opportunities for SME's, research organization, academic institutions, and industry associations to bring high quality personnel into the facility to solve key industry challenges with the intent of employing these personnel both directly and indirectly. Mitacs, IRAP, the University of Alberta and the Northern Alberta Institute of Technology have all engaged in research projects at the project site.

The intent of the ABWIP has been to attract and support commercially viable technologies/processes and/or products that have enticing market pull, while allowing each company to gain access to the necessary infrastructure and resources required for their work without limiting their ability to pursue their business development strategies. This has been achieved with AWD and their work with their subcontractor to receive and preprocess waste streams, with IRSI through their operation of thermal treatment equipment and production of raw biochar, with NER through their utilization of residual biomass as an energy source for soil remediation, with TrustBIX through their modification and deployment of their traceability software for waste materials, with Green Analytics through their life cycle assessment for carbon offsets related to biochar production, and with Annelida/Tidal through their integration of raw biochar into their growth medium for mushroom cultivation.

B. INTRODUCTION

Sector Introduction:

1. Waste management
    - The waste management sector can benefit substantially from the thermal treatment equipment and processes developed during this project.

- Waste management includes all varieties of waste streams from construction and demolition waste through to contaminated soils.
- Residual biomass waste streams can be processed and used as an effective feedstock both as an energy source and as a precursor for bio product production.
- Within this sector, the traceability solution was deployed and tested to validate an effective process for tracking waste streams and retaining the appropriate data points to generate monetized value for carbon offsets.

2. Bioindustrial
    - The bioindustrial sector includes the design, fabrication and refinement of bioindustrial technologies and their resulting bio products.
    - During this project the utilization of thermal treatment technologies for the production of thermal energy and bio products was carried forward by project partners.
    - The resulting products that were produced (syngas, biochar, activated biochar, remediated soils) were utilized in a variety of ways to produce value.
3. Carbon offset quantification
    - Carbon offsets are reduction of carbon emission or storage of carbon through a variety of technologies or processes.
    - During this project a traceability software and complimentary LCA were generated and deployed to track waste streams, thermal treatment processes and provide a calculation for offsets.

Knowledge or Technology Gaps:

- The AWBIP is providing a space for late stage TRL technologies to be deployed and field tested in a real-world environment.
    - The following image shows the gap that is faced in Alberta's bioindustrial sector
- Utilization of thermal energy generated through the thermal destruction of biomass to drive secondary processes
    - 1. For indirect pyrolysis and the generation of raw biochar
    - 2. For the indirect remediation of contaminated soils
- Computation fluid dynamics modelling, processing engineering, and mechanical engineering have been carried out extensively to understand and improve these processes
    - Testing of raw biochar produced has been completed
    - Comparison of experimental data and theoretical findings – ongoing literature review and publication of articles by IRSI staff
- The AWBIP, through a *Challenge Paper,* is using the CDS process to begin addressing additional challenge areas for the site. Suggested challenge areas include:

- Using excess materials or energy to create value – There is excess energy, wood, concrete, landfill residual and aggregates at the site. How can these items be processed in order to increase their value? This work has been undertaken at the site. Excess energy has been directed through an air to air heat exchanger for the heating of buildings on site and the offsetting of natural gas consumption. Preprocessing of waste streams has increased the diversion of metals and concretes, which has directly resulted in increased revenue generation of the site.
- Provide better technologies for handling of materials in preparation for their utilization in bioindustrial applications. Sorting, crushing, shredding and separation occur at the site daily. Can better, less costly, more intelligent technologies be deployed at the site and compliment current activities? Equipment utilization for improved preprocessing of feedstocks have included a shredder, screener and air knife separator, as well as improved process handling by AWD and their subcontracted partner on site.
- Reduce operational costs or consumption – Can technologies be leverage toward making operations at the site more efficient?
- Compete with lower value options in producing higher value products or outcomes. Landfill is currently the low-cost alternative for many waste streams. Can higher value technologies be implemented which do not rely on subsidy or regulation in order to divert material from landfill? Thermal treatment technologies for both biochar production and soil remediation have demonstrated that these uses can be cost competitive with landfilling of material.
- Increase the value of current materials – The site produces wood, aggregate, metal and landfill residue. How can we further enhance the value of these items (ex. wood to compost, recycled aggregate to cement products, biochar to activated carbon)? Activation of raw biochar at a lab scale has been carried out and successful, with future steps moving towards a bench scale pilot system for activation. Wood chips, preprocessed at the site, have been used as an additive to thermophilic compost processes. Wood chips, preprocessed at the site, have been distributed to the Dapp Power Plant as a feedstock to be blended with high moisture content woody biomass for electrical energy production. Separated concrete materials have been crushed and sold as aggregate.
- Measurement – The site will serve to calibrate measurement of emissions, consumption and costs. These can then be used to measure other projects at different scales. This work has been executed by project partners and demonstrated the carbon offset potential for future Smart Transfer Sites that are building on the activities undertaken at this site. Data collection is imperative to maximize the value of the site's operations and maximize profitability.

- The development of a *Smart Transfer Site* at the AWBIP involves the tracking, recording, and aggregation of key pieces of data.

- The buildings on site have their data points tracked through 8760 and Green Metrics instrumentation.
- All waste streams brought to the AWBIP which are handled either by AWD, their subcontractor or IRSI have dump tickets generated to track their total weights.
- All pertinent data developed during the operation of IRSI's thermal treatment equipment is tracked to inform the production of the downstream bio products (syngas, thermal energy and raw biochar).
- Proximate and Ultimate analysis, as well as more detailed testing periodically, is carried out by IRSI to ensure that both the front-end pre-processing of feedstock and the resulting raw biochar is suitable for the site.

C. PROJECT DESCRIPTION

Knowledge/Technology Description:

The four core project objectives outlined in the project application are:

1. The development of value-added applications/products from waste streams through field trials leading to full commercialization.
    - Thermal treatment technologies operated by IRSI at the site have resulted in the production of high-quality raw biochar meeting CFIA and OMRI certifications.
    - The thermal treatment technologies have also been validated at a field demonstration scale with completed engineering work for future iteration of the equipment for full commercial sales.
    - AWD and their subcontractors have demonstrated that the preprocessing of residual biomass materials can provide them as suitable feedstocks for electrical power generation at biomass plants. Additionally, these processed materials can serve as a suitable product for absorbent applications.
    - Development of a traceability system for the tracking of waste streams, processing parameters, and resulting products has been field demonstrated and validated at the site.
    - Full Life Cycle Assessment of the biochar production process has demonstrated a viable CO2eq offset through the production and application of raw biochar materials.
    - Lab scale activation of raw biochar to produce a high-quality activated material has been undertaken and demonstrated during this project.
    - Field demonstration of raw biochar blended into a growth medium for mushroom cultivation has been carried out by project partners at a satellite facility.

2. The acceleration of demonstration stage technologies and processes through field trial activities.
    - IRSI has validated the field demonstration of their thermal treatment equipment for the processing of residual biomass into high quality biochar.
    - IRSI has validated a lab scale activation technology for further activating raw biochar into an activated charcoal product. Forwarded looking plans will further refine this technology at the bench pilot scale.
    - Post processing equipment has been fabricated for the processing of raw biochar into suitable grades for sale.
    - NER has validated their indirect rotary kilns care capable of producing high quality raw biochar from residual biomass, as well as demonstrated that the thermal energy produced from biomass can be suitable to carry out soil remediation.
    - Software program for the tracking of waste streams has been developed and demonstrated at the site, with promising future applications both at the facility at with other prospective clients.
3. Access to essential engineering, software, and consulting resources for pre-commercial SME's who have viable technologies/processes applicable to this sector
    - Extensive engineering work has been carried out during this project for the fabrication and operation of a variety of equipment. This engineering work includes: computational fluid dynamics, mechanical fabrication drawings, chemical engineering calculations, mass & energy balance calculations, structural engineering, and electrical engineering.
    - Development of tracking software has been carried out during this project with the intent to aggregate data points for all waste streams and resulting bio products. Analysis of potential carbon offset protocols has been evaluated.
    - Complete Life Cycle Assessment has been carried out through consulting activities with project partners and the Challenge Dialogue System has been employed to identify and resolve challenges facing the site.
4. Working closely with research organizations, industry associations, and academic institutions to resolve industry challenges and train high quality personnel utilizing the Challenge Dialogue System.
    - A Mitacs project has been undertaken during this project working with the University of Alberta to retain a phD candidate working with biochar for soil applications, specifically in relation to compost blends and overall soil health.

- A capstone project from the Alternative Energy Program at NAIT has been supported in collaboration with the University of Alberta to evaluate lab testing of biochar products for soil health and the operation of thermal treatment equipment at the site.
- A number of academic journal articles have been published by the project partners working in collaboration with a variety of partners.
- The project partners supported a research team that was evaluating a mobile lab testing application for raw biochar production.

Project Objectives Continued:

- Class 1 IBI raw biochar has been produced using nothing more than wood biomass as the fuel source at the site.
    - Testing from Innotech and ALS
    - Full testing for grow cube from Innotech
    - Activation of IRSI's raw biochar using a proprietary hybrid activation technology has yield very positive results
    - Development of a lab scale activation system in house at the site and positive results with activated raw biochar
    - Additional engineering work to develop a bench pilot scale activation system for the site
    - Integration of raw biochar with growth medium for mushroom cultivation
- Pre-processing of waste streams at the AWBIP has led to new opportunities for providing feedstock to other bioindustrial activities
    - Agreement with a biomass power plant has been developed to divert woody biomass processed at the site
    - Pre-processing of waste streams has generated a small particle sized fine material that has downstream applications as an absorbent
- Validation of the IRSI rotary kiln indirect pyrolysis system as an efficient and feasible way to produce large volumes of consistent biochar has been carried out and validated at the site
    - CFD reports and associated testing generated by project partners
    - Utilization of residual thermal energy to heat buildings on site has been carried out during this project
    - Calculation of total carbon offset value through the process of producing biochar has been carried out
- Validation that NER can utilize thermal energy produced through a combustion chamber to fuel their indirect remediation process

- Testing of raw biochar materials on site have contributed to an understanding by the project partners of the preprocessing of feedstock, operating parameters and resulting characteristics of the raw biochar
- The engineering services have been impacted by COVID-19. Less opportunity in the market currently for engineering and consulting services. However, IRSI staff have published multiple articles during the course of this project.
- The CDS process has been deployed and is being utilized to identify challenges at the site and attract participants for the AWBIP. This process has been stifled by COVID-19 but is still moving forward.

Updates to Project Objectives:

Through the course of this project the objectives have stayed consistent. Some variation has happened in terms of project deliverables. Primarily, the second half of this project saw a growing opportunity to generate data points to quantify value in the carbon offset activities that were being pursued at the site. This growing opportunity translated into the inclusion of two project partners that allowed for the development of a traceability software solution and a clear understanding of the carbon offset potential of the biochar production process activities carried out on site. Additionally, one of the deliverables that developed during the course of this project was the importance of preprocessing residual biomass for thermal treatment processes. As this work was refined and improved it became clear that an abundance of residual biomass that would typically be landfilled could be diverted into new, value added opportunities. An initial project objective, encapsulated in the above third point, regarding the availability of engineering, software and consulting capacity was intended to be the basis of a shared working space at the site. As a result of COVID this did not materialize in a physical space at the site. However, the key objective, delineated above, was successful, but it took the form of remote work and collaboration, rather than direct face to face activities.

D. METHODOLOGY

This project followed a research and development methodology to explore, test and validate technologies and processes carried out at the project site. The varied activities that were undertaken during this project can be broken up and discussed separately below.

Preprocessing of Waste Streams:

In order to ensure the appropriate quality of residual biomass was produced the configuration and sorting process evolved throughout the duration of this project. The handling of material as it was initially received at the site was adjusted numerous times. Additionally, a variety of shredding and

grinding systems were employed to test the best approach to processing residual biomass streams. Ultimately the process evolved into a five step process that was finely tuned by the project partners.

Thermal Treatment Technologies:

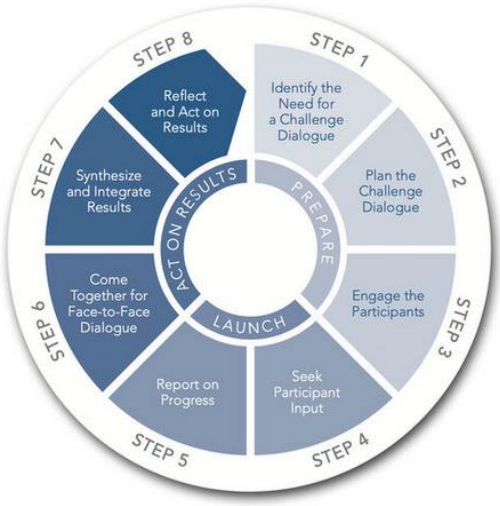
The thermal treatment technologies deployed during this project were continually refined and improved until they were operational at a commercially viable level. Computational Fluid Dynamics as well as operational parameters and resulting material testing were used to validated improvements and track outputs from the equipment.

Traceability Process:

The traceability process leveraged previous work undertaken by TrustBIX and their existing software used for livestock traceability as a starting point. A clear understanding of the material handling and thermal treatment process at the site was explored and used to form baseline information points for the traceability software.

Challenge Dialogue System:

The Challenge Dialogue System is an established methodology that was followed during this project when it was applied to project problems. The 8-step iterative process is used in tandem with the development and reiteration of the challenge paper. Attached in the appendices is the challenge paper produced for this project that delineates the process in more detail. The figure below is a simplified image that lays out the key 8 steps.



Tidal/Annelida Raw Biochar Growth Medium:

Tidal/Annelida used lab testing to blend a variety of compositions of IRSI's raw biochar and Annelida's vermicompost to develop a growth medium for mushroom cultivation in a vertical farming system. These results have yielded very promising results for specific blends and will be utilized moving forward.

E. PROJECT RESULTS

- IRSI
    - Technology refinement which includes the thermal processing of woody biomass for biochar and heat production. As well as the utilization of residual heat through an air to air heat exchanger for heating of the buildings at the project site.
    - IRSI has produced CFIA and OMRI certified biochar that exceeds Class 1 International Biochar Initiative Standards.
    - IRSI is in active discussions with three groups on the fabrication and deployment of their next iteration of their thermal treatment technology for new sites. This equipment would be further refined from the work undertaken during this project.
    - Project partners are moving forward to secure a second material receiving site for processing of waste streams to support activities and resources at the project site.
    - IRSI has produced and tested biochar pellets, growth cubes out of raw biochar for cannabis production, activated biochar from multiple lab scale technologies, a post processing step for raw biochar, a thermal treatment system for heat production, and a pyrolysis system for high quality raw biochar production.
- NER
    - Woody biomass as a suitable heat source for their thermal desportion units.
    - Biochar production while running remediation activities that meet Class 1 standards outlined by the international biochar initiative guidelines.
- AWD
    - Revenue generating relationship with sub contracted site operator for waste materials
    - Preprocessing of waste materials received at the site to generate offtakes for a variety of applications, reduce landfilled material, and offset carbon associated with the production of virgin materials.
- TrustBIX
    - Development of a traceability system for waste streams

    - Integrated data collection and aggregation with LCA for biochar production to showcase the potential for carbon offset potential

- Annelida/Tidal
    - Successful testing of raw biochar integration into grow blocks for mushroom cultivation
    - Cascading use of biochar/vermicasting growth medium for mushroom cultivation in soil remediation applications
- Green Analytics
    - Successful completion of the LCA for the production of raw biochar at the project site.
    - Assessment and validation of offset protocols for CO2eq tons.

F. KEY LEARNINGS

Key Activities:

The first milestone saw a number of key activities and subsequent key learnings that followed out of them.

Key activities:

- Utilities setup for the site to provide space for thermal treatment equipment to be installed
- Office space setup for project partners to work out of
- Assessment of yard space and office space for future tenants – renovations in office space carried out. Unfortunately, COVID-19 limited the viability of the co-working space during this project but in the future the intent is to fill this office space.
- Sourcing of residual biomass materials for testing
- Site activities detailed and mapped in process flow diagrams
- Material handling equipment deployed
- Scale setup and dump ticket information generated
- Yard space setup and organized
- Site organized and material placement established
- Industrial waste characterization challenge underway
- Key site staffed hired
- Software purchased and setup for engineering activities
- Mechanical engineering and computational fluid dynamic simulation carried out for thermal treatment equipment during the duration of this project
- Equipment purchased
- Baseline greenhouse gas offset report generated for thermal treatment of residual woody biomass and land applied raw biochar
- Level 1 analysis report for the thermal and electrical energy used at the AWBIP has been carried out
- Thermal oxidizer and indirect system for soil remediation is setup and commissioned for proof of concept

- Raw biochar product launched – OMRI certification completed and CFIA certification in process
- A number of samples have been produced and tested of both feedstock and raw biochar
- Full baseline calculations completed for greenhouse gas offset at AWBIP
    i. This informed future LCA and tracking software development
- A clear understanding of energy used by the AWBIP and commercially viable opportunities for utilizing energy produced by the thermal treatment equipment
- Front end material handling process tailored to AWBIP activities

Key Learnings:

The central technological objective for this project is to generate knowledge on the operation of a thermal treatment unit, fueled by woody biomass, that is producing thermal energy for an indirect pyrolysis system, that is producing an organic charcoal, and a thermal desorption unit, that is remediating contaminated soils in a fully automated and continuous process, that is robust and highly efficient.

Due diligence research is being conducted at NAIT and the University of Alberta through a Mitacs and NSERC Engage project. NAIT and University of Alberta are studying the capabilities and limitations of existing pyrolysis equipment and processes (ie. Updraft gasification, retort auger system, slate chain conveyor, bench scale rotary drum system), as well as the properties of organic charcoal, the properties of associated feedstocks and the operational parameters that can maximize the value in the outputted product (ie. Organic charcoal) for commercial markets. We additionally identified a limitation in the ability of current technologies to produce high volumes of consistent organic charcoal from non-fully homogenous feedstocks. Current processes are uneconomical for our market and limit the value of multiple revenue streams (ie. Reduced tipping fees, bio-product output, usable thermal energy, potential to generate electrical energy, and reduced pre-processing activities). Existing approaches are stand-alone and require input petrochemical fuel to carry out the heating of the systems and to begin the thermal treatment processes. As a result of the need for a consistent feedstock for the thermal treatment process to fuel both the pyrolysis and soil remediation processes the park has had to source and deploy equipment to process available waste streams into a close to homogenous feedstock. Through the manual sorting, shredding, magnet metal removal, particle separation, air separation, and final redundancy to remove rocks and metals the AWBIP team has dramatically improved the front end processing of materials to ensure the viability of the thermal treatment process to both reduce landfilled material and provide suitable thermal energy for the above listed tasks.

The success of these activities can be seen by the improvement of the raw biochar produced and the improvement of the characteristics in the feedstock for the thermal treatment processes. Similarly, the CFD simulation models have successfully demonstrate a suitable amount of thermal energy is available for both the pyrolysis and soil remediation processes.

Significant problems that were faced during the onset of this project have been resolved and the production of usable thermal energy, suitable to drive the pyrolysis and soil remediation processes, has been achieved. Although the focus of this work, to date, has been to generate reliable thermal energy for the production of high-quality biochar, the lessons learned during this work apply directly to the soil remediation process that was demonstrated by NER with their equipment.

Key Activities and Learnings from Final Milestone:

The activities in the final milestone, as outlined in the *Milestone, Reporting and Payment Schedule document* that accompanied the *Scope Change Request Form,* include: ongoing site operations, source additional participants for the park, market expansion for technologies and products, completion of CDS project, quantification of key data points for final report to Alberta Innovates, and the assessment of Key Performance Indicators outlined in the original project application. The only noteworthy deviations from the original workplan have been the splitting of the final milestone into two milestones and the replacement of the value-added bio-composite pellet project with the vertical farming, composting, traceability, and alternative bio-product development projects.

In addition to the above listed activities the final milestone has seen additional site participants secured for the AWBIP, operation of the NER thermal desorption unit to produce high quality biochar, and the further development and marketing of the AWBIP to the bioindustrial sector. Funding from Alberta Innovates as well as the park participants has allowed for the further development of the bioindustrial sector and will provide support for the development of viable bioindustrial processes/technologies and products.

The All West Bioindustrial Park has continued working through the COVID-19 pandemic and while utilizing the appropriate safety precautions has continued to move forward through the remainder of the project. Although some of the activities for this project have been delayed, the majority of work outlined in the original application has carried forward without delay. The viability of a co-working office space has been significantly impacted by COVID-19, however the site has made adjustments to accommodate staff on site and remote working has been utilized when applicable.

Some final key learnings that were gleaned in the final few months of this project include:

1. The significant interplay between temperature, velocity, and volume as it pertains to heat transfer.
2. The importance of managing and accounting for pressure drop when moving thermal energy through ducting and thermal treatment equipment.
3. The importance of utilizing computational fluid dynamic modelling and mechanical engineering modelling to validate assumptions relating to heat transfer, material integrity, and the causal relationships between dependent systems. Having the ability to trial a configuration in a virtual space resulted in positive outcomes verses not carrying out this type of simulation.
4. Baseline data points and a complete life cycle assessment are essential to maximizing the value of a carbon offset plan as well as traceability software.
5. Raw biochar is a tremendously valuable addition to growth mediums for mushroom cultivation – ideally at a 4% application rate.
6. Cascading value for raw biochar, vermicastings and residual mycelium is very achievable and could be deployed for in-situ soil remediation.

G. OUTCOMES AND IMPACTS

Project Outcomes and Impacts:

- The technology gap, generation of thermal energy and bio products from residual waste biomass, has been addressed through the duration of this project. The project partners have undertaken the front-end processing of residual biomass to ensure that it can be utilized by the appropriate thermal treatment equipment. Collectively the project partners have demonstrated that residual biomass can be used as a feedstock for the generation of low-quality charcoal, with suitable land applications, and for the generation of high-quality thermal energy that requires only a small propane torch to start the heating process. Once operating the utilization of biomass has been demonstrated to be effective for the generation of both high- and low-quality charcoals or biochars, in two complimentary systems. Once the indirect pyrolysis process is generating a syngas the complimentary systems, working through an integrated configuration, fully combust the available syngas, generate additional thermal energy, drive an air to air heat exchanger, and output saleable biochar materials, while simultaneously reducing waste materials and generating carbon offsets.
- The process of generating useable thermal energy from residual biomass has been demonstrated and validated by the project partners. A commercial project was carried out to reduce fuel costs and utilize thermal energy generated from waste woody biomass to remediate contaminated soils. Additionally, modifications to current commercial equipment was carried out to generate a high volume of marketable quality biochar. This work was informed by the activities at the AWBIP and demonstrates the viability of current indirect soil remediation systems for raw biochar production and carbon sequestration. By demonstrating this success, the project partners have closed a gap in the soil remediation space by allowing an alternative fuel (ex. woody biomass) to be a suitable option for thermally driven soil remediation projects. Not only does this work reduce the expected operational costs for commercial projects, by reducing input costs for fuel, it generates three new revenue streams. The first is a potential tipping fee for woody biomass, the second for a biochar product, and the third through carbon offsets, which coupled with the tracking solution developed through the second half of this project are quantifiable and marketable.
- The collective project partners have worked together to develop a life cycle assessment for the activities undertaken at the AWBIP during this project. These activities include waste diversion, biochar generation, heating of buildings on site, material processing, and biochar post processing. This LCA demonstrates that under the current parameters being utilized at the AWBIP for each ton of biochar approximately two to two and a half tons of CO2eq are being offset. Moving forward this baseline data will be used to generate a new revenue stream for the project partners during regular operations and biochar production. Additionally, this baseline information provides a benchmark for the current equipment and provides clear recommendations for future

equipment and site operations to ensure that the production of biochar is maximizing the carbon offset and thus maximizing revenue generation. The knowledge gap that has been closed here is directly tied to the specific greenhouse gas offset potential of this project and the correlated site operations.

- The collective project partners used the aforementioned LCA for the specific site to inform the collection, aggregation, and accessibility of data points through a custom designed software solution for the traceability of materials. The tracking software is able to record dump ticket information for all waste materials, collect information on product inventory for bio products, track distribution of bio products (ex. biochar), and retain this data in an accessible centralized location to generate fungible, saleable carbon offset commodities. The technology gap addressed in this instance was relating to the configuration of a suitable software system to carry out the above listed tasks. The knowledge gap was around which data points needed to be collected and how a mass balance approach could be refined to ensure transparency and accuracy with data collection for divert waste materials.
- Not only was biomass processed for the utilization by the thermal treatment equipment on site at the AWBIP, it was also processed and diverted to a biomass power plant to generate electrical energy. The knowledge gap being addressed was the appropriate receiving and processing of lower quality woody biomass diverted from otherwise landfilled material.

Student Work

- Mitacs project with phD candidate Mohammad Khodaei and supervised by Dr. Derek MacKenzie at the University of Alberta
  - General objective for this project: *"The general objective of this project is to examine the effect of biochar application in different agricultural operations of Alberta, as a means of reducing GHG, sequestering carbon in soils, and improving soil health and agricultural sustainability."*
- Sponsorship for a capstone project out of the Alternative Energy program at NAIT.
  - Project purpose statement: *"The team will participate in the production of biochar using diverted woody biomass and agriculture crop/residues for the analyses of biochar efficacy in soils and submit the analysis report to the Guidance Team by* ***April 14th, 2022."***
  - Project team members: Duncan Chan (NAIT), Ho (Jacque) Le (NAIT), Chris Olson (IRSI), Dr. Derek MacKenzie (UofA), Mohammed Khodaei (UofA), and Hassan Khodaei (IRSI).
- NSERC project with Dr. Rajendar Gupta and his team at the U of A.

- Title of this research project: *"Study of biochar Drying and Pyrolysis Kinetics in a Laboratory and Application of the Data in Modelling Large Scale Industrial biochar Plant"*
- This full report is attached as an appendix below.

- NSERC project on raw biochar and concrete blends. This project was submitted in 2021 and was just this month confirmed for funding. This project will be carried out by Douglas Tomlinson and Scott Chang at the University of Alberta.

H. BENEFITS

During the duration of this project there have been a number of realized benefits. Economic, environmental, innovation capacity and a lesser extent social benefits have been a direct consequence of this project

Economic:

The economic outputs from this project can first and foremost be demonstrated by the revenue generated and saved during the duration of the project. AWD and the company they subcontracted to undertake the material handling at the AWBIP have generated approximately $180,000.00 in gross revenue per month through their operations and material processing. Additionally, project partners generated measurable savings of approximately $15/ton with approximately 550 tons of waste material per month – resulting in a savings of approximately $8,250.00 per month. Project partners have utilized the configuration of their thermal treatment equipment to process a contaminated material at their location in Edmonton. Future projects will benefit directly from this work and will have a measurable reduction in their operating costs. Project partners have generated approximately $18,000.00 per month in tipping fees for residual biomass, while producing saleable raw biochar priced at $279/cubic yard. Production of raw biochar has fluctuated but all material produced during this project has been sold and future cubic yards of material have orders waiting to be filled.

Numerous staff have been hired or deployed for the activities undertaken during this project. Between all project partners approximately 20 FTE have been employed. Project partners have both hired indirect employees for their respective activities including fabricators, material and equipment vendors, electricians, engineers, lab technicians for material testing, and contractors. Going forward these FTE will be maintained at the AWBIP and will likely grow as the site continues to expand. Investment partners will be engaged going forward to fabricate the next iteration of thermal treatment equipment and establish future Smart Transfer Sites that will benefit from the entire scope of work carried out during this project. These future sites will have thermal treatment technologies that have been conceived and improved during this project, will utilize the tracking software developed, will modify and deploy specific life cycle assessments , and will integrate the combined understanding of these data products to maximize carbon offset value. The material handling and material processing undertaken by the project partners' will additionally inform the layout and operation of future sites.

There are multiple sites and potential investors who have shown interest in replicating the site operations at the AWBIP as well as folding in their operations to the AWBIP activities. The focus for these future sites would be on waste management and bio product generation, while the inclusion of future AWBIP participants would revolve around expanding carbon offset potential of the site and improved waste handling/diversion practices. The connective tissue for each site would be carrying out activities, outlined through an LCA, that maximizes carbon offset value. The tracking solution will be deployed to track all pertinent data through the receiving, processing and treatment of waste streams. Potential future sites are envisioned to be Smart Transfer Sites where carbon offset revenue becomes a driving force to not only increase revenue generation but to in fact facilitate increased diversion strategies and improve GHG reduction processes at the facilities as well as the AWBIP.

Environmental:

During the duration of this project approximately 20,000 tons of waste materials have been kept from the landfill. These materials were primarily wood biomass but also includes metal, concrete and asphalt. Residual biomass if landfilled would have released carbon that would have had no beneficial use. Through the activities at the AWBIP processing residual biomass for the site as well as off-site activities, carbon emissions are being reduced. Each ton of biochar produced by IRSI generates two to two and a half tons of CO2eq offsets. Included in this calculation is the value of IRSI offsetting natural gas consumption at the site through the use of an air to air heat exchanger to utilize residual heat from the equipment for heating of buildings on site. Each Thermal Desportion Unit operated offsets approximately 14,000 CO2eq tons per year of operation. The research and development carried out during this project's activities will not only increase the economic viability of the project partners activities by reducing their operational costs, but it will further increase their overall value by reducing carbon emissions and creating the potential to quantify carbon offsets for a new revenue stream.

Social:

The social benefits of this project relate directly to a shift in the waste management space and decentralized power production that acknowledges in Alberta the value of waste streams. Allowing the traceability software developed through this project to collect data on and track all waste streams this project has demonstrated that using waste to produce valuable bio products and usable thermal energy for heating can be an effective way to generate carbon offsets. Processing of wood biomass has been shown to be a feedstock for soil remediation activities (which offsets carbon emissions by supplanting a carbon fuel), a feedstock for biochar production (biochar is primarily carbon that is land applied), a feedstock for the production of thermal energy (which offsets carbon by supplanting a carbon fuel), and as a feedstock for electrical energy generation. Using this project as the foundational concept for future Smart Transfer Sites showcases the opportunity for communities to manage waste more effectively, reduce landfill space, generate value added products, offset and monetize carbon, and decentralize power production – both thermal and electrical. The successes of this site will be built upon at future sites where these activities will be further refined and further developed and will allow the AWBIP to continually adopt and deploy novel technologies, companies, and processes to further improve the site and related sites.

Building Innovation Capacity:

This project resulted in the hiring of two highly skilled mechanical engineers. It also helped to support and facilitate the immigration of a phD candidate working now at the University of Alberta through a Mitacs project sponsored by one of the project's partners. Additionally, during the duration of this project two students from the NAIT Alternative Energy Project were able to get exposure of the operations at the AWBIP and lab work at the U of A with the aforementioned phD candidate through a sponsored capstone project. A partnership was arranged and executed between project partners and a capstone project through the University of Alberta to develop a mobile testing lab for raw biochar products. Through these activities eight academics and engineers at varying levels of STEM were supported and collaborated with.

I. RECOMMENDATIONS AND NEXT STEPS

Long term plan to commercialize:

- NER has used a system to process woody biomass as a fuel source and produce a low-quality biochar. Will continue to develop this process
- NER has utilized their commercial technology to produce high quality biochar and has the potential to become a large biochar producer in Canada
- Project partners will license software that was modified for waste tracking through this project for bioindustrial and waste management clients. The site will be the first user of this software and another local Edmonton company has been engaged as the next client, with future plans to grow this business to a number of future sites and customers.
- The project site will continue to operate to receive and process waste streams for the current participants at the AWBIP as well as future participants. Through the collective project partners large volumes of processed woody biomass have been diverted from landfill and this will carry forward.
- A new site is being established to meet the demand for additional residual materials. This site will continue to refine the preprocessing of waste streams and is working with a plastic recycler to produce an alternative fuel for clients in Alberta.
- IRSI has interest from multiple parties for the future iteration of their thermal treatment equipment refined and operated during this project. Future sites operating IRSI equipment will include the traceability solution developed at the site, the preprocessing process of waste streams, the generation of an updated LCA for carbon offsets, and the postprocessing of raw biochar into suitable grades and sales.

- IRSI and a partner company have a commercial agreement for the sales and marketing of raw biochar. This relationship has served to distribute all raw biochar produced at the project site during the duration of this project. This will form the foundation for all future biochar sales.
- IRSI has demonstrated with their equipment during this project that mix of feedstocks can generate high quality biochar and therefore future partners and sites can include a range of materials. This has expanded the commercial opportunity for thermal treatment equipment and specifically the generation and sale of high-quality biochar.

Next two years:

- Work will continue as is at the project site. AWBIP and their subcontractor will receive, process and sort material for the thermal treatment equipment on site. AWBIP will bring in new companies to fill spots when they are able. Currently the majority of space at the yard is occupied by tenants but new space is anticipated to be opened in the next fiscal year.
- IRSI will operate thermal treatment equipment on site to produce raw biochar for sale and to generate a tipping fee. The further operation of their equipment will inform all future designs and sales of thermal treatment equipment.
- IRSI anticipates within the next two years having a minimum of one new piece of thermal treatment equipment designed, fabricated, and in operation in Canada. This will coincide with the setup and operation of a new site likely processing a variety of waste streams.
- The traceability solution developed during this project will be marketed to waste management and bioindustrial partners with the intent of accurate data collection and the monetization of carbon offsets. This work will be spearheaded by the NewCo formed out of a selection of project partners.
- Integration of the vertical farming activities for mushroom cultivation and/or vegetable growth will be executed at the project site and likely an additional site growing out of this locations partnerships.
- The integration of raw biochar will continue for mushroom cultivation and will expand the regional sales for raw biochar.

Potential partnerships:

- New potential partners include any participants or companies that are in the waste management space and are looking to be involved in a field demonstration of their technology, product or process.
- NewCo developed within licensing of IRSI technology, software, and partnering with to generate LCA for the commercial deployment of the tracking software.
- Project partners establishing a vertical farming expansion at the current site.

- Partnering with one of potentially three sites for the fabrication and deployment of the next iteration of thermal treatment technology. This will also include a partnership with NewCo for the deployment of the traceability solution.
- Current project partners partnering with an Edmonton based SME that recycles plastic materials, to produce a blended alternate fuel.
- Project partners will be working together in 2023 to package low volume bags of IRSI's Black Matter biochar for retail sales.

J. KNOWLEDGE DISSEMINATION

Published Journal Articles

1. Khodaei, H., Patino, D., Rico, J., Jin, Q., Olson, C., multi-objective utilization of wood waste recycled from construction and demolition (C&D) and characterization of the products, Accepted in Waste Management, Jan 2022 (Impact Factor: 7.145) In press https://www.sciencedirect.com/science/article/pii/S0956053X22003257?dgcid=author

2. Khodaei, H., Gonzalez, L., Chapela, S., Porteiro, J., Nikrityuk, P., Olson,C.,CFD-based coupled multiphase modeling of biochar production using a large-scale pyrolysis plant, Under review in ENERGY, May 2020; Impact Factor (7.1) https://www.sciencedirect.com/science/article/pii/S0360544220324324?casa_token=xZRWwVbz8NcAAAAA:0_7O2OTyXcG1NstMlOw0lGi_Pguk_YjuVx200hNY5oRXFd4tqQBWz5JEkmOugA3otkYaIi3jgcE

3. Khodaei, H., Olson, C., Nikrityuk, P., Numerical investigations of the impact of inflow conditions on characteristics of a large-scale pyrolysis unit, ENERGY Volume 169, 15 February 2019, Pages 1101-1111, Impact Factor (7.1) https://www.sciencedirect.com/science/article/pii/S0360544218324411?casa_token=ZpWyj4QqLc8AAAAA:glr6nX6Fp00FiSwSfgkMrW3feKu7XZcsQ-c57lAN7HaLWvDJayz15xWl6GAnh_JUZ6T_RvLmBwY

4. Khodaei, H., Olson, C., Nikrityuk, P., CFD based analysis of premixed and non-premixed co-injection of biomass volatile matters and air in an industrial indirect pyrolysis plant. Accepted in The Canadian Journal of Chemical Engineering (May 2020) Impact Factor (1.6) https://onlinelibrary.wiley.com/doi/full/10.1002/cjce.23915?casa_token=_uQzN56gyIwAAAAA%3Amct2DYsiQ_QUDONkSMEtro6m5L2fSY1V6NVJ-uX5odbZ4UtV7sbt9ef4wvjH8mCPsJ_gJCqhPeIXWDs

5. Khodaei, H., Yeoh, G., Guzzomi, F., Porteiro, J., A CFD-based comparative analysis of drying in various single biomass particles, Applied Thermal EngineeringVolume 128, 5 January 2018, Pages 1062-1073 Impact Factor (5.25) https://www.sciencedirect.com/science/article/pii/S1359431117337730?casa_token=Yi64dhep

OCsAAAAA:lRg26eMG5b1rpycIPZmgjnHrLM9BDDsijq4_Y0_Ml01FXAivH6oV4mDiLAk1nbWm1JS6uSNPzq8

K. CONCLUSIONS

During this project a variety of activities were undertaken, a number of objectives were achieved, key results generated, learnings both produced and refined, and outcomes moving towards next steps were realized.

The key project objectives were broken up into four statements, outlined above. The first objective was 'the development of value-added applications/products from waste streams through field trials leading to full commercialization.' The second objective was 'the acceleration of demonstration stage technologies and processes through field trial activities.' The third objective was to provide 'access to essential engineering, software, and consulting resources for pre-commercial SME's who have viable technologies/processes applicable to this sector.' The final objective was 'working closely with research organizations, industry associations, and academic institutions to resolve industry challenges and train high quality personnel utilizing the Challenge Dialogue System.' Delineated throughout this report and contained in the included appendices these four objectives were met through a variety of activities carried out by all of the project partners.

The key learnings of this project relayed on the research and development methodology to produce high quality outcomes that reiterated learnings throughout the duration of this project. From the material handling of waste streams, the thermal treatment of a variety of materials, through to the traceability of waste streams and bio products, the project partners work studiously individually and in aggregate to identify and improve upon the key learnings throughout this project. Following from these key learnings were the results of the project. Insights gleaned include the benefits of bioproducts produced from the collective processes, their respective applications to market, the carbon offset potential of these activities and processes, the revenue generation opportunities from these synergistic processes and technologies, and the full commercialization of these respective activities. The site will continue forward as a Smart Transfer Site, generating revenue through waste materials and diversion from landfills. The thermal treatment technologies will be carried forward from this work; project partners will be fabricating and deploying their indirect rotary kiln pyrolysis process for new projects in Western Canada as well as utilizing their experience in alternative fuels on commercial projects, where applicable, going forward. The traceability software developed during this project will in licensed and incorporated into the value proposition for a NewCo that will utilize this software, as well as project partners' expertise in life cycle assessment work, and thermal treatment equipment. This NewCo will be incorporated, with investment already available, to produce new Smart Transfer Sites, in part, modelled after this project.

The resulting benefits include social, economic, environmental and high-quality personnel. The aggregation of activities undertaken during this project were accelerated by the support from Alberta Innovates to a point where tangible commercial activities will be direct outputs. Socially the undertakings carried out during this project empowered the project partners to work collaboratively and seek out innovative solutions that might not otherwise have been as accessible. The traceability solution and the accompanied LCA demonstrate the tangible value for the production of raw biochar from waste streams. Not only is this a revenue generation opportunity but an instrumentally important environmental stewardship activity to shift the way contemporary society envisions waste management and decentralized power production in Alberta and Canada as a whole. Through project partner activities and involvement with academia this project has support the building of innovation capacity through high quality personnel and key research findings that will foster future growth in their respective fields.

The next steps resulting from this project are, in the project partners' opinion, the most exciting. The formation of a NewCo for the carbon offset market, traceability of waste streams and utilization of thermal treatment equipment is in the works and has funding available. Through the remainder of 2022 and 2023 this company will move into the bioindustrial space to maximize the value of this project. Learnings form this project will open new opportunities for commercial activities and will provide the ability for the generation of complimentary revenue streams and cost savings for the soil remediation field. AWBIP will continue to manage the site as a transfer location and provide waste materials to key partners as well as looking to incorporate new companies to the site to further improve waste handling and diversion. Over the next few years the carbon offset potential, active Smart Transfer Sites, revenue generation, and employment will grow as a direct result of this project the activities undertaken by the project partners. In the next two years it is anticipated that $5M in investment will be generated, 15 to 20 new staff will be recruited and hired, and tens of thousands of CO2eq offsets will be generated.