ALBERTA INNOVATES

CLEAN ENERGY 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 Energy 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.

ALBERTA INNOVATES

CLEAN ENERGY FINAL PUBLIC REPORT TEMPLATE

1. PROJECT INFORMATION:

Project Title:	**Converting spent grain to biofuel using Thermal Vacuum Reactors (TCR)**
Alberta Innovates Project Number:	2491
Submission Date:	Jan 25, 2020
Total Project Cost:	$141,500 (budget), $171,515 (actual)
Alberta Innovates Funding:	$70,750
AI Project Advisor:	Mehr Nikoo

2. APPLICANT INFORMATION:

Applicant (Organization):	**The Grizzly Paw Pub & Brewing Company Ltd.**
Address:	310, Old Canmore road, Canmore, AB, T1W 0J7
Applicant Representative Name:	Dominique Lagloire-Galipeau
Title:	CFO
Phone Number:	403-678-2487 x102
Email:	dominique.lagloire-galipeau@thegrizzlypaw.com

3. PROJECT PARTNERS

Please provide an acknowledgement statement for project partners, if appropriate.

RESPOND BELOW

N/A

A. EXECUTIVE SUMMARY

Provide a high-level description of the project, including the objective, key results, learnings, outcomes and benefits.

RESPOND BELOW

The Grizzly Paw Brewing Company located in Canmore, AB aimed to demonstrate the use of organic waste dehydrators (Thermal Vacuum Reactors (TCR)). The TCR is a sub-pyrolysis unit in early development from Alberta-based ECO-growth Environmental Inc. The system will convert spent grain waste into a condensed and highly calorific biofuel by reducing the moisture content, size and weight of the organic waste.

The spent grain waste is currently being sent 130km away to a feedlot in Airdrie. While avoiding the landfill, it is an imperfect method of managing waste. In addition to the extensive transportation costs, the nutritional value of spent grain has been analyzed and we are uncertain that it is an efficient way of supplying the feedlot with feed. Funding from Alberta Innovates will allow the Grizzly Paw to replace this method and best manage this irreducible waste from the brewing process.

The produced biofuel is intended to be used in a biofuel boiler to fulfill a local business partners' energy needs. The biofuel will replace natural gas or coal electricity, therefore generating carbon offsets.

While the project is almost cost neutral over the long term (~13 yrs), funding from Alberta Innovates will allow the Grizzly Paw to accelerate the project, tackle the large initial costs and alleviate the risks associated with demonstrating the nascent Thermal Vacuum Reactors at a larger scale.

If successful, this demonstrative project has the potential to extend to other breweries or other large producers of organic waste such as hotels, apartment buildings, cafeterias, restaurants, etc. It will reduce the amount of organic waste dumped in the landfill and eliminate GHG emissions (40lbs CO_2e/lb of organic waste) from anaerobic decomposition in a landfill. It will also reduce GHG emissions by replacing coal and natural gas energy with clean biofuel and it will reduce energy costs for businesses implementing the biofuel boiler. It will reduce the cost of transporting and landfilling waste for the businesses implementing the TCR and reduce GHG emissions by limiting transportation of dry material locally.

Ultimately, this project has the potential not just to greatly improve the Grizzly Paw Brewing Company's waste management, but to extend throughout the craft brewing industry and their partners throughout Alberta.

B. INTRODUCTION

Please provide a narrative introducing the project using the following sub-headings.

- **Sector introduction:** Include a high-level discussion of the sector or area that the project contributes to and provide any relevant background information or context for the project.
- **Knowledge or Technology Gaps:** Explain the knowledge or technology gap that is being addressed along with the context and scope of the technical problem.

RESPOND BELOW

Background

Managing spent grain waste from the brewing process is of concern to any brewery. With the extensive amount of organic waste coming from each brew, it is especially important for an exploding Alberta craft beer market (there are now 70 craft breweries in Alberta) to deal with this waste properly.

It is common practice among breweries to send the spent grain to the landfill. For the last 5 years, Grizzly Paw has been sending spent grain waste to a feedlot to divert the waste from the landfill. However, this process has proven to be ineffective and wasteful. It involves pick-ups every 10 days, rental of large container bins, and emits a smell as the grain decomposes quickly. Composting is not an option in Wildsmart Canmore at this time. It represents the transportation over 130km of a heavy, wet product with moderate nutritional content.

Challenges

The shipping of the spent grain is costly. This comes with the environmental costs of gasoline (6T of CO2e/year). Moreover, the digestion of the spent grain on the feedlot is eventually processed into further emissions of carbon dioxide, methane and nitrous oxide from the feed lot stock.

The Grizzly Paw has therefore been searching for some time to find a cleaner, cheaper, more efficient solution to this common problem. A solution has come in the form of nascent technology developed by ECO-growth Environmental Inc., an Executive Mat Service affiliated company in Calgary, AB.

Opportunity – an innovative solution

ECO-growth Environmental Inc. has developed a patent pending 'Thermal Vacuum Reactor (TCR)' or 'sub-pyrolysis' machine that converts wet organic materials into an effective biofuel (dry spent grain is 8640 BTU/lb, wood is around 8000 BTU/lb). The dry material can then be used as fuel in a biofuel boiler. For the Grizzly Paw Brewing Company, this would result in a more environmentally and financially viable option. The spent grain would be dried and hopefully used at a Laundry facility, as fuel to power up a biomass boiler, replacing natural gas. We believe that this is the right thing to do and will allow the Paw to operate our facilities in an environmentally friendly and economically sustainable fashion.

C. PROJECT DESCRIPTION

Please provide a narrative describing the project using the following sub-headings.

- **Knowledge or Technology Description:** Include a discussion of the project objectives.
- **Updates to Project Objectives:** Describe any changes that have occurred compared to the original objectives of the project.
- **Performance Metrics:** Discuss the project specific metrics that will be used to measure the success of the project.

RESPOND BELOW

Technology Gap

However, the Grizzly Paw's spent grain volume entails a need to expand on an already early-stage technology. To manage the Grizzly Paw Brewing Company's March through October higher brewing volumes and consequent larger daily waste volumes, a new, in-development sub-pyrolysis machine would have to be used to avoid a back-up of waste that would occur in a smaller system. These 2 machines could handle twice the load of the current largest TCR, processing 1000lbs of wet organic waste each a day. The machine is commercially untested, includes a new 3-phase power and dewatering systems. The Grizzly Paw Brewing Company would be the first commercial test of such a large iteration, with only a handful of businesses having implemented one of the currently available 125lb, 250lb and 500lb systems including the ATB building in downtown Calgary (500lbs), the Blackfoot Hotel (500lbs) and a Cochrane-based Tim Hortons (125lbs). To make the project viable and successful, the Grizzly Paw is to associate with a company that would consume the fuel that the TCR would produce. The biofuel produced would generate approximately 780 000 000 BTUs (200,000 kwh or 820GJ). The Grizzly Paw requires a natural gas high pressure steam boiler. The ECO Growth boiler does not produce steam or enough heat for the beer brewing process. Therefore, the biofuel boiler would need to be installed at a partnering location.

Energy savings of 820GJ ($3K/year for natural gas) would provide a payback for the boiler. The Grizzly Paw's waste represents only 10lbs/hr of dried material. The biofuel boiler can accept up to 40lbs of material per hour. The potential savings in natural gas for the boiler owner are $11K/year, which provides a quick return on investment. This also requires convincing other businesses to start dehydrating their organic waste to provide enough fuel to power up the biofuel boiler full time. Financial support from Alberta Innovates greatly accelerated the Grizzly Paw's ability to begin collaborating with local organizations.

Following the implementation of this project, there would be extensive GHG reductions. First, the biofuel boiler would replace natural gas (820GJ – 41 metric tons of CO2e) with the biofuel produced by the Grizzly Paw alone. Even larger energy replacement is possible when other organizations in the Bow Valley start dehydrating their waste, the Grizzly Paw Pub being first in line. Further GHG reductions would come from the shorter transport of spent grain, from wet heavy material being transported over 130 kilometers, to dry condensed material being transported locally.

TECHNOLOGY

The technology (Thermal Vacuum Reactors (TCR) and biofuel boiler) was available from ECO Growth Environmental Inc. with a patent pending for machine sizes of 125lbs, 250lbs and 500lbs per day. The 1000lbs per day machine that GP is planning on acquiring was a prototype and The Grizzly Paw acted as the testing ground for the oversized machine. ECO Growth Environmental Inc. continues to own the intellectual property, while The Grizzly Paw has an operating license and extended warranty.

The proposed technology is a scale-up from current organic waste reactor technology currently in BETA testing in Cochrane. Reactor uses electric thermal energy to reduce waste weight by 80% or more. The Organic waste dehydrator is patent pending. It uses a combination of heat and a vacuum sub-pyrolysis (temperatures around 200F) environment. The environment lacks oxygen, does not reach the temperature where molecules change. The water from the waste is vented outside like a clothes dryer, allows maintaining of the internal negative pressure. The new TCR's include a water condensate through a new heat exchanger to recover heat. The system runs as a batch system for now – but can be continuously fed, only discharges per batch. The system keeps some warm/dry material inside to heat up the new incoming wet material.

After the drying process, the remaining dry waste has under 20% moisture and is converted into biofuel for use in proprietary hydronic boiler system. "We take that 500 pounds of wet food waste straight from the kitchen and reduce it by 75 to 90 percent to make about 125 pounds of dry biofuel," says Glen Smith, VP of business development. "After processing the biomass material is virtually odorless".

Clients simply dump the raw waste into the reactor and walk away. The reactor automatically deposits the biomass, which resembles dry earth, into the bin when it's finished processing. Unlike compost outfits that have to pick up regularly to cut down on odors and pests, Eco-Growth can schedule pick-ups of biomass when collection bins are full to further lessen the initiative's carbon footprint.

Produced biofuel is a compatible fuel for Eco-Growth's line of hot water boilers. There are currently two boiler systems up and running, one at the Executive Mat Service laundry facility in Calgary and the other at a YMCA in Regina heating the swimming pool water.

D. METHODOLOGY

Please provide a narrative describing the methodology and facilities that were used to execute and complete the project. Use subheadings as appropriate.

RESPOND BELOW

Testing Objectives:

Prove the hypothesis that the TCR can reduce organic waste's volume and weight

Determine the best way to operate the TCR

Prove the hypothesis that the offsite boiler can generate energy with the dried waste

Show that there are GHG savings in the process

Testing Description :

During the testing phase, at the Grizzly Paw site we experimented with:

1- Dewatering the grain first in a hopper system designed by EcoGrowth

2- Quantity (weight/volume) fed into the dryer

3- Time spent in the dryer

4- Quantity (weight) after drying

At the lab, the following tests were performed:

1- Elemental analysis (phosphorus, potassium, nitrogen, sulfur) for wet & dry waste

2- % of moisture vs dry matter (DM) for wet & dry waste

3- Calorie Heat Value for dry waste samples only

We have tested one dehydrator's capacity and efficiency at reducing the weight and volume of the spent grain. We also tested the elemental analysis of the spent grain (wet & dry) as well as its heat value (dry).

We have tested 11 batches between July 30 and October 12 and had to stop for risk of freezing. The dryer is located in the unheated garage and the exit chamber & auger fill up with wet material. This could freeze overnight and result in breakage. The exit chamber design has since been changed.

E. PROJECT RESULTS

Please provide a narrative describing the key results using the project's milestones as sub-headings.

- Describe the importance of the key results.
- Include a discussion of the project specific metrics and variances between expected and actual performance.

RESPOND BELOW

During the testing we were able to establish that the material goes to 20-22% of its original weight after the drying cycle. Average moisture reduction of 74.6%.

Knowing that the Grizzly Paw could produce around 175lbs of dry fuel per day at 6,800BTU/lb this would mean a total of 1,190,000 BTU's (345kw) per day produced. The dryer uses 90kw per day, the boiler is 80% efficient. The net energy gain is 186kw/day.

+345kw fuel	-90kw dryer	345kw@80% = 276kw	Net: 186kw/day

Item	**Project CO2e addition / reduction**	**Current practice**
Trucking leftover wet grain to feedlot: 30% of current practice Dryer: 393kg/24hrs, 365 days = 143,445kg/yr not sent to feedlot	6.01 T CO2e 2 @ 30% = **+ 1.80 T CO2e**	Truck all wet grain to Feedlot = **+ 6.01 T CO2e**
+ Energy to power dryer (90kw/day, emissions factor 0.59)	**+17.77 T CO2e**	**0**
+ transport of dry Fuel to Calgary laundry plant (weight reduction 80% wet to dry, 20 trips / yr, 105km away)	**+3.24 T CO2e** (note that this transportation can be done with trips already occurring through mat cleaning runs, not "especially planned for GP" trips)	**0**
Repl. Nat. Gas in laundry boiler plant: 6800BTU/lb. Wet processed: 143,445kg = 315,579 lb/yr @ 20% dry = 63,116lb/yr dry fuel produced	63,116lb fuel @ 6,800BTU/lb = 429,187,440BTU = 452.82 GJ NG saved or **-22.82 T CO2e**	**0**
Net CO2e generated (saved)	**-0.01 T CO2e**	**+6.01 T CO2e**
Net variance: savings of 6.02 T CO2e		

F. KEY LEARNINGS

Please provide a narrative that discusses the key learnings from the project.

- Describe the project learnings and importance of those learnings within the project scope. Use milestones as headings, if appropriate.
- Discuss the broader impacts of the learnings to the industry and beyond; this may include changes to regulations, policies, and approval and permitting processes

RESPOND BELOW

Step 1: determining correct layout and feasibility of the dewatering / holding system and removing it completely. Improving the design of the EGOR

We worked with EcoGrowth to find the right design of the hopper system for the space available. We have found that the spent grain has very limited shelf life and that it is not practical to hold it to dry later. It needs to be processed right away. We tested 2 different styles of EGOR, with the second version being more efficient than the first. The aeration and evacuation of the moist air is crucial to the efficiency of the system. An improvement to the design of the paddles, paddle placement, as well as a better evac system were designed. EcoGrowth is currently working on an emptying system of the dried grain that is more efficient and seals better – therefore keeps the wet grain from escaping.

Step 2: determining the right "recipe" (qty and time) for spent grain to dry efficiently

It was important to determine the correct quantity of grain vs the amount of time needed to dry the grain. 1000 lbs of fresh spent grain takes around 24 hrs to dry. The level of moisture left in the grain is around 25-28%. However, the texture of the grain doesn't allow for pelletizing as is and needs to be combined with a binding agent (coffee grinds, other organic biomass). The grain can be used "loose" in the biomass boiler but it might make for easier handling when turned into pellets or briquettes.

Step 3: using dry spent grain as biomass fuel allowed the laundry facility to reduce natural gas consumption

Various tests: elemental analysis, level of moisture still contained in the grain and cal/g value were done. The heat value of spent grain at 25-28% moisture is around 7,200 BTU/lb. If fully dried, it is around 9,300 BTU/lb. As a comparison, wood pellets are around 8,000-9,000BTU/lb. If the boiler was running at full capacity (40lbs of biomass/hr) this would be equivalent to 6,912,000 BTU/day (7.29GJ/day) in natural gas savings. Work was also done to adjust the speed of the conveyor feeding the boiler to match the aquastat requirements.

The EcoGrowth team was responsive to suggestions and is doing their best to improve the machines as we go. The doors insulation, handles, program timing, paddles placement, exit mechanism and even the casters/legs of the machine are under review. Many of those items have already been changed on updated designs. We had several problems with the first version of the machines and especially with the hoppers and the EcoGrowth team was eager to improve and resolve the issues.

G. OUTCOMES AND IMPACTS

Please provide a narrative outlining the project's outcomes. Please use sub-headings as appropriate.

- **Project Outcomes and Impacts:** Describe how the outcomes of the project have impacted the technology or knowledge gap identified.
- **Clean Energy Metrics:** Describe how the project outcomes impact the Clean Energy Metrics as described in the *Work Plan, Budget and Metrics* workbook. Discuss any changes or updates to these metrics and the driving forces behind the change. Include any mitigation strategies that might be needed if the changes result in negative impacts.
- **Program Specific Metrics:** Describe how the project outcomes impact the Program Metrics as described in the *Work Plan, Budget and Metrics* workbook. Discuss any changes or updates to these metrics and the driving forces behind the change. Include any mitigation strategies that might be needed if the changes result in negative impacts.
- **Project Outputs:** List of all obtained patents, published books, journal articles, conference presentations, student theses, etc., based on work conducted during the project. As appropriate, include attachments.

RESPOND BELOW

Project outcomes:

The Grizzly Paw was able to:

1. Test and demonstrate an upscaled version of the EGOR dryers, processing up to 1000lbs per day of wet spent grain into biofuel.
2. Test and demonstrate the integration of the high efficiency heat exchangers into TCR to improve energy efficiency
3. Tested (and eliminated) the idea of dewatering and holding spent grain in hoppers. This can be a project for another company specializing in hoppers!
4. Demonstrate the integration with the biomass boiler unit.
5. Reduce needs in transportation of the spent grain to a feedlot by transforming heavy and wet spent grain into biofuel (not all breweries have access to a feedlot)
6. Replace natural gas with spent grain biofuel

Spent Grain and Biofuel Testing			
Specification	**Rationale**	**Frequency & Duration**	**Result**
Moisture content (SG)	Biofuel specifications are the most important criteria in defining: drying efficiency in TCR and suitability of being used as a fuel in EcoGrowth boiler	Weekly, 2 mo	80.4%
Moisture Content (biofuel)		Weekly, 2 mo	25.9%
Heat Value (biofuel)		Every 2 weeks, 2mo	3833 cal/g or 6901 BTU/lb
Elemental Analysis incl. potassium & sulfur (N, P, K, S)		Every 2 weeks, 2mo	N: 2.9%, P: 0.5%, K: 0.4%, S: 6%

Performance Evaluation		
Unit	**Spec**	**Result**
TCR	Retention time of spent grain in reactor	24 hrs for 1000lbs
	Mass balance	75% moisture reduction
	Energy balance and efficiency	Uses 90kw per day, net energy gain is 186kw/day
	Operation cost	$6/day (energy) + 1hr work labor/day
	Operational challenges	Electronics not timed with moisture level, exit chamber
Biofuel Boiler	Combustion efficiency	80% efficient
	Operation challenges and reliability	Programming the fuel conveyor to the boiler depending on the fuel consistency

H. BENEFITS

Please provide a narrative outline the project's benefits. Please use the subheadings of Economic, Environmental, Social and Building Innovation Capacity.

- **Economic:** Describe the project's economic benefits such as job creation, sales, improved efficiencies, development of new commercial opportunities or economic sectors, attraction of new investment, and increased exports.
- **Environmental:** Describe the project's contribution to reducing GHG emissions (direct or indirect) and improving environmental systems (atmospheric, terrestrial, aquatic, biotic, etc.) compared to the industry benchmark. Discuss benefits, impacts and/or trade-offs.
- **Social:** Describe the project's social benefits such as augmentation of recreational value, safeguarded investments, strengthened stakeholder involvement, and entrepreneurship opportunities of value for the province.
- **Building Innovation Capacity:** Describe the project's contribution to the training of highly qualified and skilled personnel (HQSP) in Alberta, their retention, and the attraction of HQSP from outside the province. Discuss the research infrastructure used or developed to complete the project.

RESPOND BELOW

There are economic benefits for this project. There are cost savings available to the buyer of the TCR unit by decreasing waste pickups and dumping fees. There are also cost savings to the owner of the biofuel boiler as the biomass fuel supplied is cost free as opposed to natural gas. There are opportunities to collect carbon tax credits when replacing natural gas with a biofuel.

There are also environmental benefits. The reduction of transport of waste between Canmore to the feedlot reduces gas consumption. The reduction of consumption of natural gas at the Laundry Facility also benefits the environment. For our project, we never treated spent grain as waste, but as feedlot food. However, in other situations where organic waste would have to be sent to the dump (where it would generate CO2 and CH4), there would be additional CO2e savings.

This is an Alberta based solution to a universal problem: organic waste and fossil fuel energy needs. In Alberta many craft breweries have been opening in the last few years and the organic waste problem could be mostly eliminated by drying the grain to be used as fuel. If municipalities get involved, it is the entire hospitality business community that could join and help energy intensive businesses improve their carbon footprint and replace fossil fuel with organic biomass.

Metrics of Results			
Success metric	**Project Target**	**Commercialization Target**	**Result**
Cost, $/t spent grain	$ 66.00	$ 33.00	$ 38.26
Energy Efficiency (MWh/T spent grain)	0.4	0.26	0.22
GHG reduction (tCO2/yr)	0	14.5	6.02
Energy value of Biofuel (GJ/T biofuel)	19.5	19.5	16.04

I. RECOMMENDATIONS AND NEXT STEPS

Please provide a narrative outlining the next steps and recommendations for further development of the technology developed or knowledge generated from this project. If appropriate, include a description of potential follow-up projects. Please consider the following in the narrative:

- Describe the long-term plan for commercialization of the technology developed or implementation of the knowledge generated.
- Based on the project learnings, describe the related actions to be undertaken over the next two years to continue advancing the innovation.
- Describe the potential partnerships being developed to advance the development and learnings from this project.

RESPOND BELOW

We have some recommendations to facilitate the integration of the TCR units into other operations:

1. Use organic waste that you cannot compost. Cost savings increase and the ROI is easier to prove.
2. Improve electronics on TCR unit to mirror moisture levels of the batch drying. This will avoid over/under drying the material.
3. Line up the various steps on TCR so they are automated i.e start clean up (empty) cycle automatically after cooling and automate the exit door opening.
4. Improve the TCR door locks, door insulation and door seals (in progress)

In order for the project to fully make sense and truly reduce transportation, the TCR owner would need a partner in the same town to use the biofuel produced. This would probably require many different companies (hotels, restaurants, work camps, breweries, cafeterias in gvt buildings, etc) to each acquire a TCR & remit their fuel to the owner of the biofuel boiler. This type of project might be easier to handle when spearheaded by one far reaching organization (hotel/restaurant association, town mayor, flagship industry, etc.).

J. KNOWLEDGE DISSEMINATION

Please provide a narrative outlining how the knowledge gained from the project was or will be disseminated and the impact it may have on the industry.

RESPOND BELOW

Kim Caron, owner of EcoGrowth, has been travelling across Canada to showcase the machines and the energy possibilities. The Grizzly Paw will be showcasing its TCR system in June at the community BBQ hosted at the brewery as well to other potential partners in town for the acquisition of a biofuel boiler.

K. CONCLUSIONS

Please provide a narrative outlining the project conclusions.

- Ensure this summarizes the project objective, key components, results, learnings, outcomes, benefits and next steps.

RESPOND BELOW

The EGOR equipment works well and paired with the biomass boiler it makes a great solution for facilities that generate lots of organic waste, where composting is difficult or very expensive and where lots of heat/hot water is needed. For example: schools, recreation facilities with a pool, prisons, large government buildings with cafeterias, large hotels or work camps in remote areas, etc.

I believe that if a town was looking to upgrade their recreation facilities, implementing a biofuel boiler powered by the town's dry organic waste would be great savings for the taxpayers as well as CO2e savings for the environment. As for feasibility for other breweries, they could be part of the project by drying their spent grain and other organic waste and supply it to the town (or another business) for fuel.

We are eager to assist new users operate their TCR machine and will continue to collaborate with EcoGrowth on improvements we can see being done to the machine to facilitate its operation.