NULIFE GreenTech

Carbon dioxide removal prepurchase application

Summer 2024

General Application

(The General Application applies to everyone; all applicants should complete this)

Public section

The content in this section (answers to questions 1(a) - (d)) will be made public on the [Frontier GitHub repository] after the conclusion of the 2024 summer purchase cycle. Include as much detail as possible but omit sensitive and proprietary information.

Company or organization name

NULIFE GreenTech

Company or organization location (we welcome applicants from anywhere in the world)

Saskatoon, Saskatchewan, Canada

Name(s) of primary point(s) of contact for this application

Kieran Lewko

Brief company or organization description <20 words

NULIFE solves real waste problems with the geological sequestration of Hydrothermal Liquefaction (HTL) bio-oil for 10,000+ permanent carbon removal.

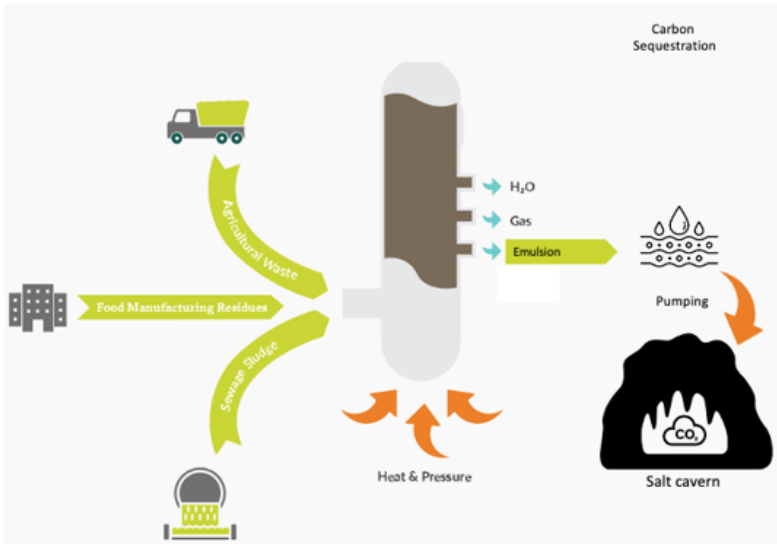
1. Public summary of proposed project[1] to Frontier

a. **Description of the CDR approach:** Describe how the proposed technology removes CO_2 from the atmosphere, including how the carbon is stored for > 1,000 years. Tell us why your system is best-in-class, and how you're differentiated from any other organization working on a similar approach. If your project addresses any of the priority innovation areas identified in the RFP, tell us how. Please include figures and system schematics and be specific, but concise. 1000-1500 words

NULIFE solves a real problem – the sustainable disposal of high moisture, industrial biomass waste. Current wet waste disposal methods are expensive, inefficient, and becoming more restricted due to landfill bans, land spreading bans and the PFAS crisis. NULIFE's patented hydrothermal liquefaction

[1] We use "project" throughout this template, but the term is not intended to denote a single facility. The "project" being proposed to Frontier could include multiple facilities/locations or potentially all the CDR activities of your company.

(HTL) process transforms these valueless waste streams into sustainable bio-oil which, through geological injection, permanently sequester carbon for tens of thousands of years. We transform environmental liabilities into climate negative assets.



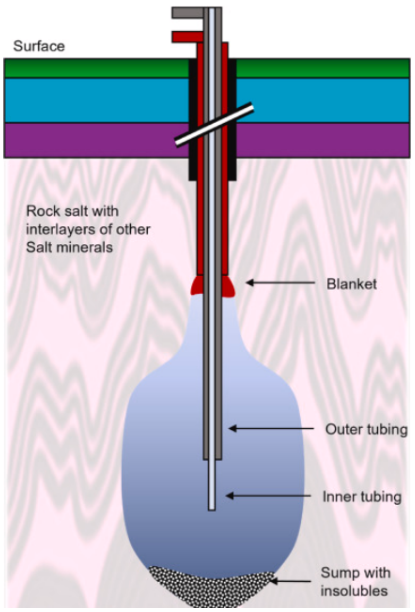
NULIFE's CDR Approach

NULIFE's patented HTL process is a continuous thermo-chemical process that breaks down and liquefies high-moisture organic materials. NULIFE's exothermic reaction occurs under high pressure (2,900 – 3,700 psig) and temperature (290 - 375°C), using water as a catalyst to reform the organic materials into long-chain hydrocarbons of sustainable bio-oil. Other output phases include biochar, aqueous and a gas phase (99% biogenic C02 with no detectable CH4). The biochar, when produced, is emulsified in the bio-oil. This is referred to as an emulsion.

HTL Process Steps:

1. Feedstock delivery into tanks.
2. Feedstock material handling.
3. Day tank into primary pumping, which generates system pressure.
4. Processor where biomass slurry is exposed to heat, pressure, and dwell time.
5. Pressure let down of effluent products.
6. Flash tank and bio-oil, biochar collection tanks.
7. Aqueous phase collection.
8. Gas phase treatment and safe release of biogenic CO2.

To ensure permanent removal of our carbon rich bio-oil, NULIFE collaborates with third-party salt cavern injection facilities. The sites are currently operational and hold several permits, approvals, and licenses necessary for operation for their relevant geographically location. Considering that injection sites often take years to permit and become operational, using third party injection partners is a strategic long-term opportunity for NULIFE to deliver immediate CDR volumes. Our partner's injection facility's operations prioritize environmental protection, with stringent controls in place to monitor for reversal/leakage and management of risks associated with water, air, soil, and vegetation.



Salt Cavern Diagram

Best-in Class HTL

- Cost effective, modular, and scalable using off the shelf equipment.
- Granted IP. 2 in 1 processor and heat exchange design.
- Pilot plant operations since 2017.
- +7 years of work with top researchers in the field.

Where we fit into the Frontier Summer 2024 Purchase RFP

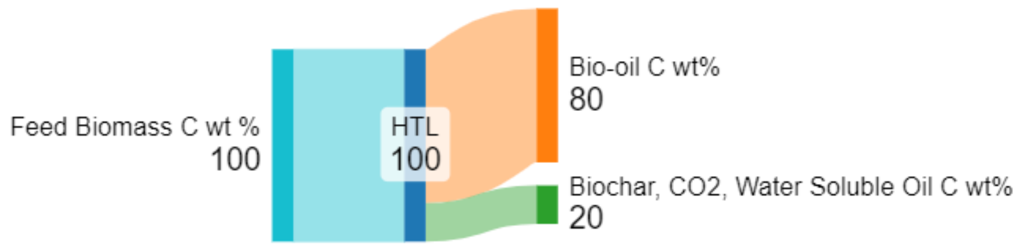
- Fills HTL gap in Frontier portfolio.
- High carbon conversion efficiency of biomass into bio-oil.
- Co-product biochar emulsified in bio-oil for higher conversion efficiency to CDR.
- Co-product CO2 is viable for CDR and/or fossil offsets.
- Validated approach to utilize contaminated and unused waste biomass with a focus on wet wastes.
- Modular approach to deployment that can tap into smaller markets.
- Leverages existing industrial injection assets to scale carbon removal quickly and at lower cost.
- Canadian location with prairie salt bed geology, abandoned oil & gas injection wells.
- Business model involves feedstock co-location and decentralized injection sites.
- Project will create advancements for the BiCRS – Bio-oil injection pathway.
- Environmental benefits associated with waste diversion. i.e., methane avoided emissions.

Sustainable Biomass Sourcing

- Initial focus on industrial biomass waste streams and by-products that are true problems for suppliers.
- Feedstocks are cost neutral, or we are paid a tipping fee.
- Feedstocks are already being collected, transported, and disposed. We fit within the value chain.
- NULIFE has no costs or emissions associated with the production/collection of feedstocks.

High CDR Efficiency and Net Negativity

- +80 wt% conversion efficiency of biomass carbon into bio-oil, with the other 20 wt% in phases that can be sequestered.
- +2.0 CDR/metric tonne of bio-oil.



Sankey Diagram Carbon Conversion Efficiency of NULIFE HTL

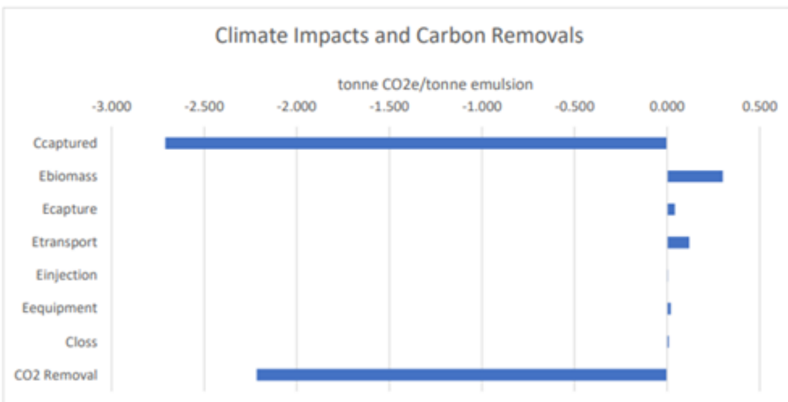


Figure 7: Climate Impacts and Carbon Removals

2024 Third Party LCA - 2.2 CDR/MT bio-oil

HTL (wet reaction condition) vs Pyrolysis (gas reaction condition)
- HTL is a more energy efficient solution for wet biomass or blends of wet/dry biomass.
- Up to 2x the carbon in HTL bio-oil. HTL bio-oil is 75 wt % carbon.
- Carbon density of HTL bio-oil improves transport and storage efficiencies.
- HTL tailgas is 99% biogenic CO_2, creating co-product opportunities.
- HTL tailgas does not contain Methane.
- Both bio-oils succumb to similar biofuel limitations. Long term, the optionality of HTL technology is much greater due to the higher energy density of the product.

HTL vs Injection of biomass
- Easier to co-locate HTL vs an injection site.
- Modular HTL technology will deploy quicker than injection wells due to multi-year injection permit timelines.
- Customer discovery consensus desire to reduce biomass transportation costs and related emissions. Due to wet biomass moisture, transport is costly and energy intensive. (Eubia)
- HTL bio-oil: 75 wt% C. Wet sewage sludge: ~10 wt% C. Bio-oil is 7.5x more carbon dense.
- Injection wells and salt caverns are geographically limited due to geology, regulations, permitting, and public perception.
- Most Class V wells are unsophisticated shallow disposal systems meant for non-hazardous material. Sludge waste is often contaminated with pfas, pathogens, etc.
    - There is a high probability that a significant % of the US class V wells are not suitable for this type of injection.

  - This creates geographical pockets that favor transporting carbon dense bio-oil.
- HTL bio-oil has a propensity to polymerize and solidify over time, which is very favorable for permanent removal and bio-oil is a more efficient use of storage space.
- We can clean and re-introduce our effluent water back it into water systems. Impactful in areas like California, where water shortages continue to occur.
- NULIFE provides optionality with CDR and long-term biofuels, which provides resilience to NULIFE's business and reduces the reliance on fossil fuels and food crops being used for fuels.

Addressing PFAS via injection

- State of Maine bans use of sewage sludge on land due to PFAS risks. (Nebra)
- Texas farmers launch PFAS lawsuit against biosolids company. (Ese)
- Our process achieves > 90% PFAS partitioning, into emulsion, with no detectable PFOS or PFOA in the output water.
- PFAS is sequestered and permanently removed.

		Eurofins Test	Eurofins Test
	2023 EPA proposed limit	Sewage sludge	NULIFE Aqueous
PFOA	4 parts per trillion (ppt)	1,500 ppt	**None detected**
PFOS	4 ppt	4,700 ppt	**None detected**

b. **Project objectives:** What are you trying to build? Discuss location(s) and scale. What is the current cost breakdown, and what needs to happen for your CDR solution to approach Frontier's cost and scale criteria?[2] What is your approach to quantifying the carbon removed? Please include figures and system schematics and be specific, but concise. 1000-1500 words

Locations and Scale

NULIFE Saskatoon Pre-Commercial Plant (PCP) - 1725 Ontario Avenue

[2] We're looking for approaches that can reach climate-relevant scale (about 0.5 Gt CDR/year at $100/ton). We will consider approaches that don't quite meet this bar if they perform well against our other criteria, can enable the removal of hundreds of millions of tons, are otherwise compelling enough to be part of the global portfolio of climate solutions.

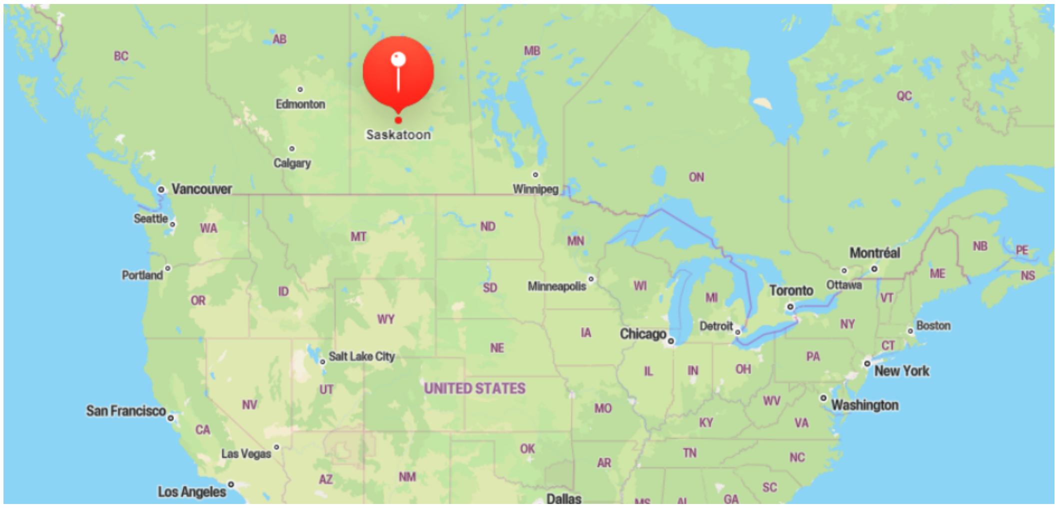


Figure 1. NULIFE's Saskatoon Headquarters & PCP

Plant	Pilot Plant	PCP Part A	PCP Part B	PCP Part C Module	Part D Commercial
Location	Hafford, SK	Saskatoon, SK	Saskatoon, SK	Saskatoon, SK	Canada and US
Timeline	2017	2023	Q4 2024	2025	2030
Status	Decommissioned	Operational	Deployment started	Under Dev.	Under Dev.
# of processors	1	1	2	12	144
# of modules	0	0	0	1	12
Flow Rate (L/min)	0.5	5	10	60	720
Max Feedstock req. annual, Dry MT	NA	650	1,300	7,800	85,000
Feedstock % cap accounted for	NA	+100%	+100%	+100% in pipeline	+100% in pipeline
Max annual CDR	NA	1,000	2,000	13,000	158,000

Pilot Plant: In 2017, we designed, built, commissioned, and began operating our Hafford HTL Pilot plant. The pilot plant used a single processor system with over 3,500 operating hours at the time of decommissioning. Most of the equipment was re used in Saskatoon. The pilot plant demonstrated our ability to produce bio-oil from various biomass waste streams, with a focus on flour mill waste residues and canola production waste residues.

PCP Part A: In 2022, we started the design process for our Saskatoon Pre Commercial Plant (PCP). In July 2023, we built our single processor system with a scale up of 10x in flow rate from the pilot plant. After the scale up from our Hafford Pilot Plant to the Saskatoon PCP, we successfully reached the optimum size of HTL processor. Saskatoon PCP is operational. We are processing dairy Dissolved Air Flotation (DAF) sludge and flour mill waste residues from local industrial food processors that are within 10km of our plant.

Wet Feedstock Tank Farm at PCP

Single HTL Processor at PCP

PCP Part B: By Q4 2024, we will add a 2nd processor in Saskatoon, utilizing existing peripheral equipment. This will double up flow rate capacity, without the risks associated with increasing the size of the processor.

PCP Module Part C: In 2025, we will increase the number of processors to create a "module" of 12, in Saskatoon at our existing location. We will utilize the two processors and all relevant equipment from PCP part B. Active discussions with local waste generators have identified enough feedstock supply in Saskatoon to build at least one module locally.

Part D: Commercial: Our commercialization strategy involves deploying HTL module(s) to accommodate the available waste at the given location. Longer term qualified sales pipeline includes multiple co-location opportunities, such as:

• WWTP in NY State: 25,000 dry MT/year of sewage sludge, which would require 3 modules. Counterfactual: Landfill.

• Upcoming SK Pulp Mill: +100,000 dry MT/year of wheat straw fines and black liquor effluent, which would require 13 modules. Counterfactual: Without Pulp/HTL project, wheat straw decomposes on SK farmland fields.

Cost Breakdown

- 0% - Feedstock acquisition.
- 70% - HTL conversion technology.
- 19% - Bio-oil transport and storage.
- 11% - MRV and quantification.
- No revenue associated to co-products.

Needed for us to achieve Frontier cost and scale

- Driving down CapEx & OpEx through economies of scale.
- Continued focus on problem waste streams that eliminates feedstock acquisition costs.
- Monetizing biogenic CO2 as a co-product via CDR and/or output market.
- Integrated CDR approach with a focus on co-located feedstock scenarios, renewable energy sources, rail transport and acquiring injection sites.
- Government incentives may also help drive CDR prices down.

Research groups and technology developers have demonstrated that HTL is amenable for a variety of individual feedstocks. These include algae, organic wastes (municipal sludge, food waste, fats/oils/greases, manure), and forestry residues.

In the United States alone, estimated sustainably sourced biomass feedstock availability is 500 million dry tonnes by 2050. In 2050, this represents +800M tonnes/year CO2 removed via the HTL/injection CDR pathway.

Approach to Quantify Carbon Removed

NULIFE's approach to quantifying carbon removed involves CO2e stored by determining bio-oil carbon wt%. CO2e emissions and counterfactuals are divided into five distinct steps, each ensuring the recording of various data points for tracking purposes: biomass sourcing/counterfactuals, biomass transport, HTL conversion, bio-oil transport, and bio-oil injection.

c. **Risks:** What are the biggest risks and how will you mitigate those? Include technical, project execution, measurement, reporting and verification (MRV), ecosystem, financial, and any other risks. 500-1000 words

Project Execution – Risks associated with scaling technology. We have mitigated this risk by building our executive team, led by experienced entrepreneurs with multiple start ups and exits. Earlier in 2024 we hired a Director of Engineering who previously led a $1B carbon capture project, adopting and scaling new technology for the development of the project. Today, his focus is scaling our technology, as well as scaling the technical and operations teams towards full commercialization. Our technology model is to leverage existing vendors and equipment for easy commercialization, not relying on custom design equipment and materials.

Project Execution – Injection site concentration risk. Risks associated with losing our injection partner would not eliminate our ability to produce bio-oil but it would impact our ability to inject it to generate CDRs. To help mitigate this risk, we have assessed multiple salt cavern disposal locations in Canada as well as the United States. The Canada prairies are home to salt bed geology and an abundance of oil & gas injection wells with over 6,500 options in Western Canada. A long-term mitigation strategy is to purchase our own salt cavern or injection well.

CDR – Buyer Risk. There is a risk that we may not be able to attract sufficient buyer interest to scale our technology, which would prevent scaling. To mitigate this risk, we are talking to many buyers and various buyer types including direct, reseller and coalitions (such as Frontier) in different jurisdictions. We are also considering smaller buyers. Our second mitigation strategy is to explore the use of our sustainable bio-oil through R&D work in other markets such as oil & gas refining, heating oil, marine fuel or stationary combustion where our bio-oil would result in avoided emissions by displacing fossil fuels.

Financial – Financing Risk. We have reduced the financing risk for this project as we have funds in the bank and grant funding in place. There is financial risk that we may not be able to raise additional funds to continue expansion beyond this project, thereby delaying our growth. This is a real concern in the current financial markets. To mitigate this, we have identified multiple government backed non-dilutive funding sources to reduce investor risk and minimize the amount of equity required to raise. Key mitigation to reduce financial risk is securing a buyer for our CDRs or our bio-oil.

d. **Proposed offer to Frontier:** Please list proposed CDR volume, delivery timeline and price below. If you are selected for a Frontier prepurchase, this table will form the basis of contract discussions.

Proposed CDR over the project lifetime (tons) *(should be net volume after taking into account the uncertainty discount proposed in 5c)*	\$500,000/\$645 = 775.2 x 1.07 = 829.5 830
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	End of 2025
Levelized cost (\$/ton CO_2) *(This is the cost per ton for the project tonnage described above, and should match 6d)*	\$538
Levelized price (\$/ton CO_2)[3] *(This is the price per ton of your offer to us for the tonnage described above)*	\$645

[3] This does not need to exactly match the cost calculated for “This Project” in the TEA spreadsheet (e.g., it’s expected to include a margin and reflect reductions from co-product revenue if applicable).