ALBERTA INNOVATES
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.

ALBERTA INNOVATES

CLEAN RESOURCES FINAL PUBLIC REPORT TEMPLATE

1. PROJECT INFORMATION:

Project Title:	***Engineering & Development of a New "Asphalt from Alberta Bitumen" Process***
Alberta Innovates Project Number:	202100905
Submission Date:	March 11, 2022
Total Project Cost:	$1,136,733
Alberta Innovates Funding:	$400,000
AI Project Advisor:	Dr. Paolo Bomben

2. APPLICANT INFORMATION:

Applicant (Organization):	**Carbovate Development Corp.**
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exempted, excluded and absolved from all liability for damage or injury, howsoever caused, to any person in connection with or arising out of the use by that person for any purpose of this publication or its contents.

3. PROJECT PARTNERS

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

RESPOND BELOW

Carbovate Development Corp. (Carbovate) would like to acknowledge and thank Thermo Design Engineering of Edmonton, AB, Process Engineering International LLC, Dr. Hesp of Queen's University, and the Ontario Ministry of Transportation for their support and contributions to this project.

A. EXECUTIVE SUMMARY

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

RESPOND BELOW

Project Description, Objective, Key Results and Learnings:

Under development since late 2018, Carbovate's patented proprietary technology has been designed to process Alberta bitumen into high quality asphalt cement binder for longer life roads. Carbovate's process, focused on asphalt as the primary product, offers a low CAPEX, high efficiency, low emissions solution due to its unique modular design, developed with Thermo Design Engineering Ltd. (TDE) of Edmonton. The simplified proprietary process has been designed to minimize energy consumption, water use, and generate reduced emissions to the environment when compared to conventional processes. Added objective was to develop a solution such that there would not be a requirement for a traditional flare.

The objective of the project was to complete the required engineering and development activities to move the Carbovate process from the preliminary process design stage to a completed, licensable engineering design. The license package is now available and includes detailed modular design, Total Installed Capital Cost (TIC) and an estimated 1-year delivery

lead time. A potential flare replacement solution has been designed and is optional in the licensing package.

A pathway for a near zero carbon footprint design has been developed for the process, without the need for carbon capture and storage.

Outcomes & Benefits:

Carbovate is working to develop a project to construct the first commercial-scale demonstration plant with all plant modules fabricated in Alberta. The intention is to provide a consistent high-quality asphalt cement product to Canadian and US markets.

Subject to further engineering, it is anticipated that the commercial-scale demonstration plant will host a unique proprietary solution to replace the need for a traditional flare; this technology would be installed in addition to a traditional flare to demonstrate and prove the effectiveness of the new technology in a commercial-scale infrastructure.

Carbovate is developing a licensing strategy to address potential global opportunities with industry leading entities.

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

Sector Introduction - Bitumen Beyond Combustion:

The traditional method of producing asphalt is to modify the residual pitch from the refining process that prioritizes fuels product and margin maximization using the residual pitch to make asphalt cement binder.

This involves investing billions of dollars in the plant infrastructure to make full fuels slates of gasoline, diesel, and distillates, as well as aviation fuels, where pitch is the residual by-product. The pitch then must be softened by blending and further processing to make acceptable asphalt cement binder.

At the end of the life of a road surface, the asphalt enters the circular economy. The pavement is recycled and classified as Recycled Asphalt Pavement (RAP). RAP is combined with 'new' asphalt cement binder and used in all aspects of roadworks.

Knowledge and Technology Gaps:

The technology gap addressed in this project: how to produce consistent high quality asphalt cement binder meeting Performance Grade (PG) grade specifications directly from Alberta bitumen using a low capital cost process while minimizing energy consumption, water use, and carbon footprint without the need for a traditional flare.

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

Knowledge or Technology Description:

The project objectives are to develop a licensable package for Alberta and global markets that would produce asphalt binder using Alberta bitumen as a feedstock, and to develop the design for an alternative to conventional flare design.

*The patented Carbovate process, CARBOVATOR*BBC6000© uses a proprietary configuration of established separation and distillation steps to directly produce high quality asphalt cement binder meeting selected performance grades from Alberta sourced bitumen. Underpinning the overall design is an "ESG by design" approach including requirements to have a minimal by-product stream and reduce the carbon footprint by minimizing electricity, fuel, and water consumption.*

The project converted the Carbovate process concept to an engineered process design package ready to license, including a Class III cost estimate. An initial conceptual engineering solution to replace the need for a conventional flare has been completed.

Updates to Project Objectives:

The project objectives were not adjusted during the project work.

The following project metrics were used to measure success in the project:

Metric	Project Target
Commercial licenses sold	licence package completed
Process Energy Intensity Reduction	estimate of up to 30% energy intensity reduction based on design package
Number of barrels used / year	
Cash spent in Alberta	CAD 500,000
Designs for modules	completed
Reduction of CAPEX	estimate of approaching 1/3 CAPEX cost reduction based on design package

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

These steps were followed to complete the project:

1. *Progressed Process Design, confirmed process scheme.*
2. *Developed the Inside Battery Limits scope, including Class III CAPEX and delivery by modular construction in TDE Edmonton manufacturing plant, and HAZOP.*
3. *Developed a License Package for ISBL Technology.*
4. *Flare alternative technology was optimized.*
5. *Process GHG Intensity was estimated.*
6. *Asphalt derived from Alberta bitumen was distilled and its grading verified in a laboratory.*

Facilities included:

TDE Engineering Office in Edmonton,

InnoTech Edmonton, and

Testing laboratories at Queen's University.

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

The following results were delivered:

For the Carbovate Process:

1. *The Carbovate process was confirmed and simulations were completed for a modular designed plant. Results exceeded expectations, adding ability to scale the process.*
2. *Complete P&ID, Heat and Material Balances, Metering Diagram, utility demands, major equipment list, material selection diagram, and HAZOP. A Class III ISBL CAPEX estimate, and length of time to manufacture estimate were developed, all enabling the process to be licensable.*
3. *The Carbovate Process ISBL CAPEX Total Installed Cost (TIC) estimate is ¾ of original TIC estimate.*
4. *Final Process description is complete, technical questionnaire is complete for prospect qualification, and license package is complete, enabling approaches to prospective licensees.*

For the Flare Alternative:

5. *Flare alternative concept was reviewed, process verified, and designed to match the Carbovate process.*

For Process Verification with Alberta Feedstock:

6. *Laboratory distillation of Alberta diluted bitumen into asphalt cement samples, process simulations, and laboratory testing of asphalt samples indicate that the Carbovate process can make consistent quality straight run PG grades (e.g., PG 58-28) needed for longer life highway construction and less repair, desired by road owners and builders.*

Project Specific Metrics

The following metrics were met during the project:

- *$400,000 in innovative production and distribution*
- *5 new sector HGSP trained*
- *Advance TRL from 5 to 7*
- *Four end users participating*
- *Two unique processes*
- *Commercial License package completed*
- *Estimate of up to 30% energy intensity reduction based on design package*
- *Designed to be modular*

The following metrics were almost 100% met in the project:

- *CAD 447,719 cash spent in Alberta, somewhat less than the planned 500,000 CAD due to realized efficiencies and Carbovate providing increased in-kind support*
- *Revised estimate for the CAPEX reduction is 25% rather than the originally estimated 1/3 of CAPEX reduction based on design package when compared to conventional process design*

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

Key learnings include:

- *From the Design:*
  - *The project hypothesis that the process would convert Alberta sourced dilbit into PG grade quality asphalt cement at a CAPEX substantially lower than current processes was proven correct.*
  - *CARBOVATOR*BBC6000© design accommodates scalability of the modular plant.*
  - *The modular plant has a small physical footprint, low energy consumption, and a minimal carbon footprint.*
  - *CARBOVATOR*BBC6000© design accommodates processing both diluted and undiluted feedstock.*
  - *The process has flexibility to provide the light and heavy gas oils making up the by-product stream separately.*
- *Inside Battery Limits (ISBL) CAPEX:*
  - *ISBL CAPEX (TIC) well below expected.*
- *Capability to carry out feedstock simulations and compare feedstocks for selection and process optimization is confirmed.*
- *The alternative flare solution, though designed for the CARBOVATOR*BBC6000©, has potential application to augment existing industrial flare solutions.*

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 and impacts:

- *Samples of Alberta dilbit drawn, distilled and tested produced straight run asphalt grades meeting PG grade specifications without need for modification. These asphalt cements tested in the laboratory were of equal quality to current Cold Lake asphalts which provide longer road life, per Alberta Innovates Dr. Hesp report "Opportunities and Challenges for Asphalt Binders Derived from Alberta Oil Sands".*
- *CARBOVATOR*BBC6000© process low ISBL CAPEX enables both low-cost capacity expansions and comparatively low-cost new installations depending on the infrastructure available at the prospective site. The process footprint of the modular plant is very small compared to conventional processes of similar size.*
- *Energy consumption and GHG emissions of the process operation are estimated to be up to 30% lower than from current asphalt production. Water requirement is very low.*

Clean Energy Metrics:

Metric	Project Target	Commercialization / Implementation Target
# New Spin-Off Companies created		2
$ in Innovative Production and Distribution	$400,000	$0
# Sector HQSP trained	5	
TRL advancement	TRL 5 to TRL 7	TRL 7 to full commercial
# projected new jobs created from future deployment		65 + 5 ongoing 133 + 112 manufacturing, construction
$ Future Investment		125 to 150 million CAD
# projected GHG emissions reductions from future deployment (to 2030)		~70% of each Bitumen barrel (4200/day) removed from combustion pool
# field pilots/demonstrations		Commercial Demonstration Plant
Partnership agreements / MOUs?		2 plus 1

All of the metrics are achieved with the following modifications:

- *Future investment, new stand-alone plants are more likely to have much lower investment required, enabling more licenses.*
- *Projected future GHG emissions are likely to be up to 30% less than current production.*
- *The market for the flare alternative process is very broad.*

Program Specific Metrics:

Metric	Project Target	Commercialization / Implementation Target
# of End Users participating	4	6
Unique product/process	1	1
$/bbl product uplift	N/A	$20/barrel
# commercial BBC products	N/A	1

All the Program Specific metrics were achieved with 2 unique processes developed.

Project Outputs:

- *Commercial License Package for the CARBOVATOR*BBC6000©.*
- *The Carbovate process has been verified to produce consistent quality straight run PG grades from Alberta Bitumen needed for longer life highway construction and less repair.*
- *Flare Alternative design completed and ready for licensing.*

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

Benefits:

The lower-than-expected cost of the modules and fast delivery supports the expectation of several process license sales within 5 years.

Each module built at the TDE plant in Edmonton brings revenue to Alberta. Supporting infrastructure requirements depend on the infrastructure needed to be added at each specific site.

The annual spend of a commercial-scale demonstration plant operations is estimated to exceed $100 million.

A commercial-scale demonstration plant is expected to process over one million barrels of bitumen annually.

The process plant design is scalable. This makes it suitable as a stand-alone plant or as a low CAPEX addition to existing capacity to meet incremental demand increases.

Environmental Benefits:

Asphalt is a "Bitumen Beyond Combustion" product because asphalt cement is a construction material, not a fuel. With the Carbovate process, over 70% of each bitumen barrel is

processed as asphalt cement binder. The binder is combined with aggregates to make asphalt roads. At the end of life the road surface materials are recycled as Recycled Asphalt Pavement (RAP) which is then mixed with smaller quantities of new asphalt cement binder for new road construction or repair, becoming part of the circular economy. The by-product is suitable as a feedstock for petrochemical products which can enter the circular economy.

The Carbovate process generates up to 30% less GHG emissions than conventional asphalt processes.

Carbovate has developed a pathway to a low carbon footprint without carbon capture and storage and with minimal purchased offsets. This has the potential to produce a much lower carbon footprint asphalt than is currently used.

The alternative flare solution has a major potential given its impact on eliminating pilot emissions, and emissions from unforeseen release events.

Social Benefits:

The Carbovate asphalt process using Alberta bitumen feedstock produces asphalt cement that can increase road life when compared to the current road life of 5 to 10 years using asphalt from the residual of the refining process. This reduces road replacement and repair substantially, with the added benefits of reduced congestion, improved safety from fewer repair sites, reduced idling emissions, and improved infrastructure efficiency.

Longer road life means lower road repair and road replacement investment, reducing required taxes.

To the extent that electrification of the transportation system reduces demand for bitumen as fuel, asphalt cement as a primary product is a growth market. It replaces the reduced production capacity from the lower crude runs. The growth supports employment and investment for on purpose asphalt production.

Building Innovation Capacity:

To satisfy licenses sold in the global market, the modular process units will be built at the Edmonton facilities of TDE. This will add another process to showcase TDE's ability to develop and design modular processes and support their engineering and manufacturing HQP employment.

H. 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

Recommendations and Next Steps:

Carbovate hopes to stimulate a commercial-scale demonstration plant and business to serve markets not currently supplied with asphalt from Alberta bitumen. Example markets are Ontario, Eastern Canada, the Upper Midwest, and Northeastern USA.

Current economic analysis shows the project to be profitable. This plant will be used to demonstrate the process to potential licensees.

Carbovate expects to sell licenses to asphalt companies with global reach potentially wherever Alberta bitumen is marketed.

*Long road life depends on using feedstock which contains the correct materials composition. The CARBOVATOR*BBC6000© extraction process retains and concentrates these materials in the form of a high-quality asphalt. Dr. Hesp's, Queen's University, studies indicate that Alberta bitumen feedstock has the correct composition and can source asphalt quality equal to the best in the world.*

Carbovate has developed a path to a near zero carbon footprint for the process. This will be an available alternative to licensees.

Carbovate is working with TDE to support the license sales and construction globally. The Company is working with road builders, municipalities and potential distributors to develop supply relationships. Carbovate continues to develop its relationship with the Ontario Ministry of Transport.

I. 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

Knowledge Dissemination:

Carbovate developed a comprehensive process licensing package to be used to introduce and describe its asphalt process. The package includes detailed description of the process, OPEX considerations, license components, and a detailed questionnaire for technical qualification of a potential license site. The questionnaire helps provide needed information to determine the cost to install and operate the plant at the selected site.

Impact on the Industry:

GHG reduction initiatives will reduce demand for refinery fuel products causing declines in crude oil runs and refinery closures resulting in reduce asphalt cement supply. The Carbovate process represents a low capital cost option to process Alberta bitumen into high quality asphalt cement binder for longer road life. This supports and develops future demand for AB bitumen as a raw material.

J. 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 objective of the project was to complete the required engineering and development to move the Carbovate process, CARBOVATOR*BBC6000©, from the preliminary process design stage to a completed, licensable engineering design (from TRL5 to TRL7), validate the process through simulation and feedstock testing as well as design a flare alternative process.*

Key components included design and cost estimation of a plant to be built in modules at an Alberta fabrication plant. Plant attributes sought were low CAPEX incorporating small footprint, low water consumption, minimal energy consumption and GHG emissions, and

developing a flare alternative process. Processing capability objectives met are to process Alberta bitumen and heavy oil feedstocks into asphalt cement binder of consistent quality with capability on a straight run basis (without post-production blending) to make PG Grades and provide attributes capable of making longer road life.

Project Results, Learnings, Outcomes:

The process design has been validated.

The license package is now available and includes detailed modular design, Total Installed Cost and estimated delivery lead time. The modular plant benefits from a small physical footprint, low energy consumption, a minimal carbon footprint and very little water consumption.

Benefits:

Benefits to Alberta include investment to build and install the planned commercial-scale demonstration plant while creating employment for skilled engineering and manufacturing professionals, laboratory technicians, plant operators and maintenance personnel, among others.

The project processes Alberta produced bitumen as feedstock, producing consistent high-quality asphalt cement, which will be processed at very low GHG emissions levels.

Alberta bitumen when processed as described can make asphalt cement binder that enables long life roads. Additional markets in North America are thought to need up to 400,000 B/D bitumen supply.

Next Steps:

Build a commercial-scale demonstration plant processing Alberta bitumen.

Demonstrate the flare alternative process at the commercial-scale demonstration plant.

Market additional plant/ process licenses