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

1. PROJECT INFORMATION:

Project Title:	**HDR Diluent Reduction**
Alberta Innovates Project Number:	AI 2390A
Submission Date:	December 15th, 2019
Total Project Cost:	$25,035,460
Alberta Innovates Funding:	$2,193,000
AI Project Advisor:	Shunlan Liu

2. APPLICANT INFORMATION:

Applicant (Organization):	**Husky Energy Ltd.**
Address:	707 8th Avenue SW, Calgary, Alberta T2P 3G7
Applicant Representative Name:	Justin Jia
Title:	Project Lead – HDR Development
Phone Number:	403-513-7860
Email:	Justin.Jia@huskyenergy.com

3. PROJECT PARTNERS

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

RESPOND BELOW

BP Canada Energy is a part owner of the Sunrise Oil Sands Partnership, is a supporter of the project, as a 50% owner of the Sunrise Facility where the pilot HDR demonstration plant was built.

However, investment into new "high risk" technology development is generally not financially attractive as compared to the portfolio of low risk company projects that leverage core competencies and meet stakeholder needs for increased production and operational enhancements. As an integrated production company, stakeholder acceptance of longer-term new technology risk and investment is challenged against more immediate ROI of projects focused on core competencies.

A. EXECUTIVE SUMMARY

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

RESPOND BELOW

This nominal 500 barrel per day development project is located at the 60,000 Barrel per day in-situ Sunrise Oil Sands Limited Partnership (SOSP) facility 60 km north-east of Fort McMurray Alberta. SOSP is jointly owned by BP Canada and operated by Husky Oil Operations Limited. Real-time conventional dilbit fed the project, diluent was recycled to the in-situ facility, and HDR product was produced. The purpose of the development project was to test scale-up, demonstrate product quality at a large scale, and demonstrate diluent reduction performance objectives reliably and predictably in order to de-risk scale-up to a commercial implementation.

HDR is a novel Synthetic Crude Oil (SCO) hydrogen donor moderated mild thermal cracking process that achieves viscosity and quality improvements simultaneously. HDR accomplishes GHG reductions by changing the bitumen molecule at the in-situ site to facilitate reducing and replacing the type and amount of diluent required for transportation and eliminates the need to boil undesirable light fractions contained in the diluent out of the diluted bitumen at the refinery. Approximately 85% of the condensate based diluent is reduced, unlocking potential additional bitumen pipeline capacity of 60% and once HDR is practiced commercially, 5.1 million tonnes per year of carbon dioxide emissions will be eliminated for every 1 million barrels of bitumen processed (14 kg GHG reduction/barrel).

The 500 barrel per day demonstration plant was designed, fabricated and installed by Q4 2018 and a series of demonstration trials were conducted in 2019. The demonstration plant was successfully and safely operated. The stage 1 trial successfully achieved all product quality KPIs and proved the hydrogen donor

concept to be valid. Additionally, an independent GHG life cycle analysis was also performed and confirmed a GHG reduction of 14kg per barrel of bitumen. The results from the GHG life cycle analysis indicate a GHG reduction of 409M tonnes per year following the commercial implementation of HDR at the Husky Sunrise facility.

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

The majority of Alberta's crude oil production is in the form of bitumen; a thick viscous fluid which is composed of complex, heavy hydrocarbons. Bitumen is too thick to flow through pipelines. Thus, in order to transport bitumen via pipeline to American Gulf Coast refineries, the thick crude must be diluted with large volumes of US diluent. The use of diluent comes at a significant cost to Canadian oil sands producers. Diluent occupies a significant portion of the pipeline capacity, reducing the space available for produced bitumen. Furthermore, diluent is purchased by oil sands producers at a premium and is sold at a discount at the destination, leading to poor netbacks.

In addition to the costs associated with diluent usage, bitumen sells at a significantly discounted value to refiners. This discount can largely be attributed to the overall quality of the crude oil. Bitumen has a low API density and has a high concentration of sulphur and other impurities when compared with light, sweet crude blends. The quality and properties of bitumen make it difficult to refine and can lead to significant greenhouse gas (GHG) emissions during the refining process.

Traditional upgraders look to reduce diluent dependency and improve the quality of the bitumen product. However, traditional upgrading processes are complicated and expensive to build making them an unpopular solution. Additionally, the traditional upgrader value chain is not built within close proximity to the producer, and thus lacks the heat integration required for a reduction in GHG emissions.

Partial upgrading technologies are cheaper and simpler to build than the traditional upgrader models and can be built within proximity to the producer. Partial upgraders, like HDR, eliminate the need for US diluent imports as it replaces diluent with locally manufactured SCO (improving the trade balance for Canada). This reduced diluent dependency increases operating netbacks for producers and increases pipeline capacity within the existing infrastructure. This increase in pipeline capacity reduces the need to build additional pipelines (and reduces risks, GHG's and costs related to that endeavor). Additionally, partial upgrading significantly improves the quality of the bitumen increasing its price value and widening its market base among American refiners.

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 Description:

HDR is an innovative in-situ partial upgrading technology. The technology is a collaborative development effort of Husky Energy, Alberta Sulphur Research Limited, Alberta Innovates Energy and Environment Solutions, and CanmetEnergy. HDR changes the bitumen molecule at the in-situ site to facilitate reducing and replacing the type and amount of diluent required for transportation and eliminating the need to boil undesirable light fractions contained in the diluent out of the diluted bitumen at the refinery. The innovative solution combines traditional visbreaking design and hydrogen donation science together and applies it to SCO reactions with bitumen.

Bitumen is blended with SCO in the right proportion and temperature to effect thorough mixing. The mixture is heated to specified temperatures through heat integrated equipment for the requisite amount of time to accomplish hydrogen donation reactions between the tetralin-like molecules and heavy molecules and achieve targeted viscosity and total acid number (TAN) specifications. The HDR product is fractionated and hydrotreated to remove olefins and is trimmed with condensate as required to achieve final viscosity specifications.

Once the technology is practiced commercially, 5.1 million tonnes per year of carbon dioxide emissions can be eliminated for every 1 million barrels of bitumen processed (14 kg GHG reduction/barrel). In addition, should HDR be implemented en masse and the existing diluent import pipelines reversed (as the import need is eliminated), the existing total bitumen export capacity could be increased by almost 60% without building more pipelines.

A 500 barrel per day HDR demonstration plant was engineered, constructed and operated at the Husky Sunrise Energy Project located north east of Fort McMurray, Alberta, to de-risk the technology for commercialization, demonstrate the technology's capability of integrating into the thermal heavy oil facility (for heat integration and GHG reduction opportunities), processing variable quality feedstock in real time, process and equipment reliability.

The HDR product will be assessed as a feedstock to its internal downstream refining groups. The combination of all these cross functional value chain development efforts could significantly increase the

commercial viability of the HDR process for rapid market uptake across oil sands in-situ producers and markets.

Project Objectives:

The main objectives of the 500 bpd HDR demonstration at Sunrise was to verify that hydrogen donor thermal cracking could be achieved in a large-scale setting and validate the GHG reduction potential through an independent GHG life cycle assessment. The aim was to demonstrate the ability to manage varying feedstock compositions, be reliable and ratable (low fouling), and meet critical product quality objectives (viscosity, stability, TAN, toluene insolubles, olefin content) at the design diluent reduction levels to guarantee market acceptance, economic returns, and position the technology for commercial deployment.

Metrics:

The specific demonstration goals included:

1. Build and operate the 500bpd HDR
2. Verify condensate diluent content below 5% and ability to use locally sourced SCO from Suncor, Syncrude, Husky, and CNRL at a volume less than 15% on an ongoing basis around the clock.
3. Achieve sustained product quality improvement to achieve better refining value as per the 0.5 barrel per day pilot plant results. (TAN, product stability, toluene insoluble (coke content), viscosity, olefin, simdis, vacuum residue content)
4. Confirm reaction conditions, equipment, and low fouling performance, which will serve as inputs to minimize full scale capital cost and to achieve an economic project.
5. Ensure wide market downstream refining acceptance can be achieved by conducting a refinery market assessment
6. Ensure pipeline product segregation is avoided – meet existing accepted WCS product specs for critical components throughout the 6-12 month trial.
7. Verify GHG reductions through modelling as many of the GHG benefits are offsite through transportation and refining benefits.

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

The following methodology was applied to aid in the successful execution of the HDR stage 1 demonstration:

1. Project Execution: The Husky Project Delivery Model is a robust project framework that outlines the process by which disciplined project execution can be achieved.
2. Safety Orientated Project Execution and Operation: A safety first mentality was heavily emphasized during the design and trial of the HDR pilot. The operation of any new technology is complex and can present many unforeseen complications. The Husky Operational Integrity Management System (HOIMS), outlines the minimum acceptable standard for operational integrity and drives positive health, safety and environmental performance. Additionally, the team chosen to design and operate HDR collectively offered the project years of experience and technical or operational expertise. This experience, in conjunction with clear safety standards/procedures were used to minimize the risk associated with the HDR pilot.
3. Practical Research & Development: The research and development performed throughout the trial was strategic and focused on improving areas with the most significant benefits using the most economic methods.
4. GHG Lifecycle Analysis (LCA): The calculation of GHG emissions was carried out using a process-based LCA approach that evaluated the emissions from each of the life cycle stages by either applying existing models that have been developed as part of the LCAOST project and developing new modules for the HDR upgrading process.

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 results of the demonstration include:

- The 500 bpd pilot was installed by Q4 2019 and was safely and reliably operated in 2019.
- The combined condensate and SCO ratio was below 20 volume percent. This indicated more than 50% total diluent blending reduction
- Sustained product quality improvement performance was achieved. The product quality achieved all KPI's:
    - Viscosity is < 350cSt @ 7.5C
    - Total acid number was below 1.1 (60% reduction)

- No coke formation (no toluene insoluble increase)
- No fouling
- Product is stable and compatible
- More valuable fractions were achieved through the process with reduced vacuum residue
- Final blend olefin will be below pipeline specification through hydrotreating

- Testing program was well planned, implemented and monitored throughout the stage 1 trial, where credible reaction condition and sizing information were obtained for the full-scale capital cost estimation and engineering purposes
- GHG reduction was verified through 3rd party assessment and confirmed 14 kg GHG reduction per barrel of bitumen.

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

Project learnings through project execution and testing:

- Demo plant design: the project faced a few noteworthy design challenges in scaling the trial up from a 1bpd pilot into a 500bpd (750 bpd throughput) demonstration plant.
- Project sanction and execution - limited resources (budget, manpower) for high Health Safety and Environmental (HSE) standard at an operating facility. The construction, operation and execution of a demonstration plant posed a significant risk, from both a financial and HSE perspective. The execution of the HDR the demonstration next to/in conjunction with the key operational asset of the Husky Sunrise facility, heightened this level of risk. Managing these two levels of risk (budget and HSE) constrained the project to achieve a balanced state between a limited budget and a high standard of execution.

The above lessons learned have been documented and will be used for future commercial design and development.

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* template. 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* template. 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

As discussed in section E, the existing project achieved all technical KPI's and proved the manufacturing capability of HDR. The success of the 500 bdp demonstration suggest that HDR is capable of reducing diluent blending and GHG emissions, while achieving the required pipeline specifications. This achievement significantly reduced risk associated with the commercialization of HDR. However, before commercial implementation can occur, the project must verify the refinability of the HDR product. This final knowledge gap may be addressed through a stage 2 trial.

Clean Energy Metrics

GHG reduction performance was verified and improved reduction performance was observed comparing the original claim in 2017. The GHG reduction was successfully verified to be 14 kg per barrel of bitumen, which will aid in achieving Alberta Innovates' 2030 target of reducing 50% of GHG emissions on a per barrel basis. Through continuous improvement, more accurate material / energy balance, sizing information and refining GHG footprint could be available through a stage 2 trial. The stage 2 trial presents an opportunity for optimization and improved performance.

Program Specific Metrics

The 500 bpd demonstration was successfully designed, fabricated and operated. The HDR pilot project achieved all product quality KPIs and proved the hydrogen donor concept to be valid. In addition, GHG reduction was verified through 3rd party assessment and confirmed to be 14 kg GHG reduction per barrel of bitumen. However, due to funding constraints the project was not able to fully evaluate the refinability of the final HDR project. A stage 2 trial would ensure wide market downstream refining acceptance can be achieved.

Project Outputs

IP Type	Country	Number	Filing Date	Status	Owner and Description
Patent	Canada	CA2912768A1	2015-11-24	Granted	Husky Oil Operations Ltd.
Patent	US	US10081769B2	2015-11-24	Granted	Husky Oil Operations Ltd.

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

Economic Benefits:

This technology supports economic diversification by improving the product value of Canada's bitumen resource. New commercial opportunities could be realized as additional facilities could be built alongside existing in-situ facilities. Improved market access could be achieved due to diluent import and export elimination.

2016 Canadian bitumen export data shows that 1.4 million barrels per day of bitumen required 600,000 barrels per day of diluent, with over 400,000 barrels per day of diluent imported and pipelined from the US Gulf Coast to Alberta. Through commercial HDR deployment, the need for imported diluent would disappear and the available pipeline capacity for crude oil export would increase. Elimination of the 400,000 bpd diluent imports and reversal of the importation line could create 800,000 bpd available export crude oil pipeline capacity.

Significant job creation opportunities may occur with commercial project implementation. An improved breakeven price has the potential to create jobs within Husky. Reacting Canadian SCO via hydrogen donation via HDR in place of blending Texas imported diluent could improve the trade balance in favor of Canada.

Commercial deployment of HDR could significantly benefit Alberta and could result in a total capital spend of over $30 billion and GDP increase of $18.3 billion by 2040 via the building of new HDR and SAGD facilities. The additional margin via HDR would lower the breakeven cost for SAGD facilities and thus support additional investments and growth.

Environmental Benefits:

A comprehensive lifecycle assessment conducted on a well-to-tank basis has been completed by the University of Calgary. The attached report provides further detail on the methodology, inputs, assumptions, and boundary. The technology GHG savings presented on the basis of emission reductions achieved per barrel of bitumen processed, are projected to be 14 kgCO2e/bbl calculated from the lifecycle boundary of well-to-tank.

Emission reductions occur due to the decrease in volume of diluent required for transportation of bitumen to the US Gulf Cost and processing of the bitumen from 30% diluent blended, to 4.5% blended by volume, a reduction of 85%. Emissions reductions are assumed to occur along the length of the pipeline(s). The baseline and project HDR scenarios assume all marginal bitumen produced in Alberta is refined in the US Gulf Coast.

At the refinery, less overall volume of product is processed with its accompanying reduction in GHG emissions. Calculations for refinery emission reductions assume that bitumen and SCO throughput volumes remain the same and diluent volumes decrease by 85%. In addition, the HDR process impacts the refinery as follows:

a) Reduced hydrogen usage since the HDR process rejects sulfur (~38% of H2 consumption), offsetting hydrogen used at the refinery; and

b) Reduced vacuum residue processed since HDR converts 20-25% vacuum residue, which is normally heated and processed in a delayed coker.

During the diluent recovery process, sour water is generated and recovered. As development is expected to occur on or near a brownfield site, the overall net new environmental impact to land and water footprint is expected to be negligible versus new construction on uncleared land.

Social Benefits:

Technologically, this proposal could solidify Alberta's technical community in how partial upgraded products affect refining operations. Should the full-scale implementation occur, the local indigenous community may benefit. Husky has made several significant investments in Indigenous stakeholder communities and views increased local investment as benefitting community resilience. Husky contributes significant funding to Fort McKay First Nation for development of a job-ready labour pool consisting of individuals qualified to work as employees or contractors in the oil sands industry.

The benefit to the community of developing services is to provide local expertise as well as provide direct economic benefit and is a key element to drive community self-determination. Furthermore, it will entrench service providers in Husky's supply chain for the HDR project.

Building Innovation Capacity:

A team of mechanical, chemical, process, and control system engineers will be required to design the project. Skilled trades professionals are needed to construct the pilot plant including instrumentation, piping and equipment installation and perform ongoing maintenance activities during the Project lifetime. The exact number of resource-hours for each phase has not been determined, however the design created 37 employment, additionally 22 indirect employment were created. When the project is commercially implemented it is predicted that 4,352 people-years will have been created, 2,772 of which were direct and 1,580 of which were indirect.

Husky has a diversity and inclusion program and as such the additional job creation may introduce new opportunities for under-represented and marginalized groups within Alberta. Additional demand for full time skilled trades could indirectly encourage an uptake in apprenticeship offerings from local companies. As part of our collaborative approach with Alberta Indigenous groups (further described in Section 8) Husky will consider working collaboratively with the local communities and businesses to build capacity and required skills.

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

The HDR pilot project successfully achieved all product quality KPIs and proved the hydrogen donor concept to be valid. However, due to funding constraints several aspects of the original project scope were not achieved. A stage 2 trial would better address the observed operational challenges and risks associated with commercialization. During stage 2, process modifications would focus on optimizing operating conditions within the partial upgrading facility. Additionally, stage 2 would look to minimize the risk of commercial implementation by focusing on understanding product market pricing, product placement and acceptance.

In parallel with the stage 2 development, commercial HDR project development is in progress to further validate the business concept and identify business opportunities. During this commercial development effort, regulatory strategy, stakeholder engagement, market assessment, economic evaluation, etc. would be exercised and examined. Based upon a successful stage 2 development and business opportunity validation, Husky will consider kicking off the commercial design contingent upon capital availability and project attractiveness following Husky Project Delivery Model (PDM) process.

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

The knowledge products as a result of this demonstration may include such items such as licenses, codes and standards, policy and regulatory development. Husky may consider licensing the technology to other operators to encourage the adoption of partial upgrading within the province. The results of the pipeline testing may also be used to inform pipeline specifications for transporting the partially upgraded product.

In addition, as much of the GHG savings occur outside of the jurisdiction in which the product is partially upgraded, the widespread adoption of partial upgrading technology could influence the development of carbon markets on a national and international scale and demonstrate the benefits of increased cooperation with an open border carbon market.

As the first partial upgrading technology to be trialed at scale in an operating SAGD environment, this Project will be a key step in advancing industry and market acceptance of the quality and refinability of partially upgraded bitumen. Knowledge transfer will occur after the refinery trial completion to advance the objective of marketing the technology and the products, along with increasing technical knowledge amongst the research and industrial community. Non-confidential and non-competitively sensitive qualitative and quantitative information trial data and key performance product quality and operations indicators as tracked in the HDR process and at the refinery may be shared at industry conferences and papers in respected industry journals contingent to Husky's corporate communications approval.

Knowledge dissemination avenues are as follows: (a) The Canadian Heavy Oil Association hosts several events and technical luncheons, an annual fall conferences, and panel discussions; (b) The Canadian Crude Quality Association and Crude Oil Quality Association (US) hold semi-annual internal meetings and annual conferences where refiners gather to discuss product quality and acceptability; (c) National Partial Upgrading Program presentation where industry members and government frequently meet; (d) American Fuel and Petrochemical Manufacturers Association annual conference; (e) annual COSIA conference; and F) Alberta Innovates annual conference.

In addition, certain information and results from this trial may be made available to the scientific community including members such as Dr. Joule Bergerson, Associate Professor and Canadian Research Chair in Energy Technology Assessment with the Department of Chemical and Petroleum Engineering at the University of Calgary who is working alongside Husky to develop the lifecycle assessment for the HDR partial upgrading technology. Dr. Bergerson is a member of the Oil Climate Index (OCI) team supported by the Carnegie Endowment for International peace in conjunction with Stanford University and the University of Calgary.

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 500 bpd demonstration was a success. The project was safely and successfully operated and achieved all product quality KPIs verifying the hydrogen donor concept within a large-scale design. Additionally, the GHG reduction was successfully verified to be 14 kg per barrel of bitumen, which will aid in achieving

Alberta Innovates' 2030 target of reducing 50% of GHG emissions on a per barrel basis. Through overcoming the project management, design and operation challenges, the experiences and lessons learned were documented and will serve for future commercial development. A stage 2 trial has been scoped and planned to address the challenges observed in the stage 1 demonstration before full commercial implementation. Additionally, the stage 2 trial will look to minimize the risk of commercial implementation by focusing on understanding product market pricing, product placement and product acceptance.