ENGINE MODERNIZATION FOR GHG REDUCTION

Ember Resources in collaboration with Waukesha, Ironline Compression and five other project partners collaborated to convert an older engine series to the latest version with a lower carbon footprint.

*Prepared by Ember Resources as part of the Methane Consortia Program*
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# Table of Contents

- Project Summary ............................................................................................................. 2  
- Technology Summary ..................................................................................................... 3  
  - Purchase and Installation Process .................................................................................. 3  
  - Project Schedule .......................................................................................................... 4  
- Emission Profile ................................................................................................................ 4  
  - Summary of GHG mitigated due to the project ............................................................... 4  
  - Abatement Cost ............................................................................................................. 6  
- Conclusion .......................................................................................................................... 6  
- Project learnings ............................................................................................................... 6  
- Technology learnings ....................................................................................................... 6
Introduction

PTAC is working with Alberta Environment and Parks to collaborate on the formation of consortia with industry to reduce emissions of methane and promote innovation in reduction mechanisms within the Alberta oil and gas sector. As part of this program, Ember Resources worked with Ironline Compression to modernize a Waukesha Engine. This consisted of an upgrade/conversion of a Waukesha 7042GL (Series 2) to the latest technology available from the Original Equipment Manufacturer (OEM), the Waukesha Series 5.

The Waukesha Series 5 consists of redesigned engine components, control systems, and catalyst technology designed to achieve substantial GHG reductions. The application of this technology reduces the carbon footprint, increase reliability, and lowers operating and maintenance costs by increasing the maintenance interval and the equipment life cycle.

Project Summary

Waukesha engines are well-known in the Canadian oil and gas industry. Decades of experience have provided the opportunity to improve engine design to increase efficiency, reliability and emission reductions capability. The Waukesha Series 5 upgrade consists of the following additions:

- Cylinder heads with improved cooling;
- Pistons with smaller crevice volumes to reduce unburned hydrocarbons and methane slip;
- A new camshaft profile to change intake valve timing;
- New turbochargers to help increase engine efficiency;
- New controls to maintain a strict air-fuel ratio.

The resulting combination of these additions leads to lower emissions and fuel consumption rates.

Ember Resources has worked with Ironline Compression in this project. Ironline was the key partner in implementation of the engine modernization. The experienced partnership led to the successful roll of the upgrade. Ironline is experienced with engine overhauls, and retrofits, and has a good working relationship with Waukesha. Below is the list of the other partners involved in this project:

- 24/7 Compression ~Red Deer
- Tiger Machining ~Edmonton
- Connelly Insulation ~Red Deer
- SOL Thermal ~Edmonton
- Spartan Controls ~Calgary

Purchase and Installation Process

Vendor selection was made through a systematic bid process. Component lists based off engine serial number were supplied by Waukesha and distributed to OEM parts and labour suppliers. Vendors then provided detailed scope of work and costs submitted back to Ember. Submissions were scrutinized, discussed, and awarded based on the information provided.
Project Schedule

Monday June 22nd, 2020
Installed OEM supplied Empact catalyst housing and wiring harness tray.

Tuesday June 23rd, 2020
Repaired tin cladding and exhaust pipe insulation around catalyst install.

Wednesday June 24th to Friday June 26th, 2020
Organized parts and deliver to site. Prepared parts to be distributed for conversion.

Monday June 29th, 2020
Started disassembly of engine and prepared for engine block machining.

Tuesday June 30th to Wednesday July 1st, 2020
Machined the engine block and installed the new lower liner fits.

Thursday July 2nd to Thursday July 9th, 2020
Reassembled the engine with the new mechanical components.

Tuesday July 7th to Thursday July 9th, 2020
Installed the new engine wiring harnesses, computer modules, and monitoring and control systems.

Wednesday July 8th, 2020
Installed the catalyst insulation cover.

Friday July 10th, 2020
Re-programed the control panel to integrate with new engine systems. Started-up the engine successfully.

Emissions Profile

Summary of GHG Mitigated Due to the Project

The project reduced unburned methane in the engine exhaust from 50 g CH₄ per m³ of fuel input to 1.5 g CH₄ per m³. This resulted in an emissions intensity reduction of 48.5 g of CH₄ per m³ of fuel input, a 97% reduction from the baseline. The Series 5 technology accomplishes this reduction by being more fuel-efficient while still maintaining stoichiometric combustion. The outcome is minimizing methane slip. Methane slip is the unburned fuel that would have been released to the atmosphere in the exhaust as pure methane (CH₄). Minimizing unburnt fuel is crucial to reducing GHGs since 1 gram of CH₄ is 25 times more impactful to GHG emissions than 1 gram of CO₂. This reduction is based on component design and control technology. A significant contributor is the piston design that reduces unburned hydrocarbons by reducing areas that trap fuel.

Another way to describe this outcome is that the engine modernization resulted in a reduction from 10 g CH₄/Bhp-hr to 0.5 g CH₄/Bhp-hr. Operating the engine at 1000 Bhp and 8760 hrs per year will result in an emissions reduction of 83.22 tonnes of CH₄ per year, which translates to a reduction in CO2e emissions of 2080 tonnes per year assuming a 25x global warming potential for methane. At the full load of 1480 Bhp, the same reduction from 10 to 0.5 g CH₄/Bhp-hr and 8760 operating hours per year equals to an emissions reduction of 123 tonnes of CH₄ per year (3079 tonnes of CO2 per year).
This reduction was proven through four similar projects by Ember Resources where Waukesha engines were modernized to the Series 5 level. These 2019 projects were supported by the Energy Efficiency Alberta Custom Energy Solutions program. They included pre- and post-emission testing to prove the emissions reductions claims of the technology. Table 1 shows the pre-conversion audit of emissions for one of these projects. It is shown that CH₄ emissions ranged from 44 to 58 g/m³. Table 2 shows the post-conversion audit of the same engine; it is noted that CH₄ emissions are now between 1.1 and 1.2 g/m³. Fuel flow measurements were used to calculate BSFC, and exhaust stack gas analysis testing was used to measure CH₄, NOx, CO, CO₂ reductions.

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<thead>
<tr>
<th>Engine Speed (RPM)</th>
<th>Engine Load (BHP)</th>
<th>NOx (g/bhp-hr)</th>
<th>NOX (g/m³)</th>
<th>CH₄ (g/bhp-hr)</th>
<th>CH₄ (g/m³)</th>
<th>CO₂ (g/m³)</th>
<th>CO₂e (g/m³)</th>
<th>CO₂e (tonnes/yr)</th>
<th>CO₂e (tonnes/hr)</th>
<th>BSFC (Btu/BHP-hr)</th>
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*CO₂ determined via carbon mass balance.

**Source:** AER Source Test Report for Ember Resources, 7-11-30-25W4 Facility, Alberta, Engine: Waukesha L7042GL, SN: C-14667/1; Prepared By: Oasis Emission Consultants, Inc., August 20, 2019

The actual results tested from engine conversions Ember completed in 2019 were normalized and led to the conclusion that the Series 5 technology reduced unburned methane in the engine exhaust from ~50 g CH₄ per m³ of fuel input to ~1.5 g CH₄ per m³, an emissions intensity reduction of 48.5 g of CH₄ per m³ of fuel input and a 97% reduction from the baseline.
Abatement Cost

Pre project abatement cost is $247.50 per tonne of CO2e per engine. These abatement costs were assumed using OEM models of pre conversion and post conversion BSFC, and exhaust stack emissions values.

The calculated abatement cost at project completion is roughly $178 per tonne of CO2e. This is based on the above referenced testing conducted in 2019 on a similar conversion for four different engines. Actual testing from 2019 proved to result in better than anticipated GHG and fuel consumption reduction results. Based on this knowledge, it is assumed actual reduction results could be higher than indicated above.

The project lifetime is estimated to be 10 years. For this project period, abatement costs are estimated at 21.5$/t CO2e (for a reduction of 2,080 tonnes of CO2e/year).

Conclusion

Project learnings

Based on historical conversions, organization and pre-planning was of high importance to ensure the project was successful in its implementation. Every detail to be completed was discussed and plotted in a shared timeline. Parts were removed from packaging and organized in an order that was needed throughout the job timeline prior to job commencement. Appropriate personnel were only on site at the required times throughout project implementation. A lot of learnings from the 2020 retrofit of the engine were focused on efficiency within project execution and alignment. The project team hopes to build off these learnings and create efficient frameworks to implement within future engine modernization projects.

The suppliers and partners mentioned above were directly associated with this project, but many other services were seen to benefit indirectly from the implementation of this project. Shipping and transport, materials provided for manufacturing, warehousing and distribution, tool, and consumables suppliers, as well as OH&S aspects of this project are indirect contributions. This type of project is seen to reduce Alberta’s carbon footprint, but also distributes positive income throughout many levels of the economy.

Technology learnings

As mentioned within the technology summary, the Waukesha series 5 has undergone substantial development to increase its efficiency, reliability, and impact in reducing GHG emissions. The newly developed piston as part of this upgrade has resulted in significant reduction of methane slips. The overall upgrade of the engine was successful and will result in significant yearly reductions in GHG over the lifetime of its implementation.

This project was a huge learning curve for the entire project team. The resilience from all parties involved to push through any challenges encountered was commendable. Due to the workload and parts required for these conversions, the cost could be considered as quite high in comparison to standard or status quo life cycle costs. Fortunately, programs such as the MCP provide the means necessary to subsidize these costs and in turn reduce GHG emissions to fight climate change while keeping budgets manageable and in alignment with day-to-day operating costs.
From: Gerald Palanca <Gerald.Palanca@aer.ca>  
Subject: RE: For approval: MCP Final Report Ember  
To: Snezhana McIver <smciver@ptac.org>  
Cc: ssharma <ssharma@ptac.org>, Marc Godin <marc.godin@portfire.com>

Wed., Jan. 06, 2021 10:56 a.m.

Hello, I don’t think I’m a voting member but if I am I believe they delivered as required so I support payment if it hasn’t been issued already. There will always be questions about the necessary level of detail included in these reports. For technical folks, it may not be enough but I suspect the vendor will provide if asked.

Gerald

From: Snezhana McIver <smciver@ptac.org>  
Sent: December 22, 2020 4:26 PM  
Cc: ssharma <ssharma@ptac.org>; Marc Godin <marc.godin@portfire.com>  
Subject: Fwd: For approval: MCP Final Report Ember

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hello,

I am following up on the note below requesting the committee to review and approve the final report that Ember Resources completed. Once the approval is received from the committee, PTAC will issue the final payment.

Thank you,
Snezhana

From: "Snezhana McIver" <smciver@ptac.org>  
Cc: "Marc Godin" <marc.godin@portfire.com>, "ssharma" <ssharma@ptac.org>  
Sent: Thursday, December 10, 2020 11:00:02 AM  
Subject: For approval: MCP Final Report Ember

Hello everyone,

Please find attached the final report for the project that Ember Resources completed. The report
confirms that the project scope and GHG emissions reductions were achieved. Approval of the report by the Steering Committee is required by PTAC for payment of the final project invoice. Once approved, the report will be published on the PTAC website.

Please reply by December 18 if you approve the final report for publication and payment of the final invoice.

Thank you,

**Snezhana McIver** | Direct: 587-891-9974

**PTAC Petroleum Technology Alliance Canada** | [www.ptac.org](http://www.ptac.org)

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From: Chris Hugenholtz <chhugenh@ucalgary.ca>  
Subject: RE: For approval: MCP Final Report Ember  
To: Marc Godin <marc.godin@portfire.com>  
Cc: Snezhana McIver (smciver@ptac.org)  
     <smciver@ptac.org>, Shay Sharma  
     (sharma@nexovcanada.com)  
     <sharma@nexovcanada.com>  
Wed., Feb. 17, 2021 03:48 p.m.

Thanks Marc,
My apology for the delay getting back.
This is clearer and I support moving forward with the invoice payment.
Best,
Chris H.

From: Marc Godin <marc.godin@portfire.com>  
Sent: February 17, 2021 2:28 PM  
To: Chris Hugenholtz <chhugenh@ucalgary.ca>  
Cc: Snezhana McIver (smciver@ptac.org)  
     <smciver@ptac.org>; Shay Sharma  
     (sharma@nexovcanada.com)  
     <sharma@nexovcanada.com>  
Subject: FW: For approval: MCP Final Report Ember

[△EXTERNAL]

Good afternoon Chris,
I hope you are keeping well.
I also hope you can soon provide us with your approval to pay the final invoice. These payments are critical in the current economic circumstances.
Thanks,
Marc

Marc Godin
403-870-5402

From: Marc Godin  
Sent: Thursday, February 4, 2021 4:37 PM  
To: Chris Hugenholtz (chhugenh@ucalgary.ca)  
     <chhugenh@ucalgary.ca>  
Subject: RE: For approval: MCP Final Report Ember
Hi Chris,
I hope you are keeping well.
I have worked with Ember and Ironline to update the report to meet your requirements. We have added data tables from pre-and post-conversion audits conducted in 2019. We also have the full audit report should you wish to see them.
Please let me know if you have any questions or comments, and if you agree, we can pay the final invoice and post this report on the PTAC website.
Thanks,
Marc

Marc Godin
403-870-5402

From: "Chris Hugenholtz" <chugenh@ucalgary.ca>
To: "Snezhana McIver" <smciver@ptac.org>
Sent: Tuesday, January 12, 2021 9:33:13 AM
Subject: RE: For approval: MCP Final Report Ember

Hello Snezhana,

Thank you for the reminder.

I reviewed the report and have the following feedback:

1. Project tone and narrative: Overall, the report reads more like a brochure than a project report. There is a mix of tense, which gives the impression much of the material was simply copied from a proposal. There is overuse of self compliments, which is inappropriate. For example, the following statement does not belong in a project report: “All parties involved have been great to work with and have proven to deliver” (Section: “Technology learnings”). Generally, I do not find the tone of the report acceptable in present form based on the way it is written to outline a glowing self appraisal.

2. Lack of evidence and detail: I did not find adequate evidence of the stated emissions reductions. There is an appearance of calculations to base claims in the section entitled “Summary of GHG mitigated due to the project”, but there are no details on the calculations and no measurements to confirm these values. I don’t accept a series of
calculations (hanging on a number of assumptions) as the gold standard for confirming reductions and abatement cost. There must be some confirmation of the stated reductions based on direct measurement, modeling, etc.

3. We need to see the equations and assumptions clearly laid out. What standardized methods were used for parameterization? What are the sources of error? The report fails to acknowledge that the reductions and abatement costs are estimated not actual reductions. What are the key sources of error? If you can’t confirm these estimates with empirical methods, then state the gaps and clearly indicate the impact on the estimated reduction/abatement cost.

b. It is stated that the estimated reductions have “been proven through a similar project at Ember Resources that involved pre and post emission testing from an EEA Custom Energy Solution project in 2019”. If so, provide a copy of this report or show other forms of evidence to connect the stated performance.

I would like to see these points addressed in a revised report before approving payment.

Best,
Chris H.

From: Snezhana McIver <smciver@ptac.org>
Sent: January 11, 2021 1:36 PM
To: Chris Hugenholtz <chhugen@ucalgary.ca>
Subject: Fwd: For approval: MCP Final Report Ember

Hello Chris,

I hope this email finds you well.

I am just following up in regards to the below email, as we require the committee's approval to proceed with payment.

Thank you,
Snezhana

From: "Snezhana McIver" <smciver@ptac.org>
Cc: "ssharma" <ssharma@ptac.org>, "Marc Godin" <marc.godin@portfire.com>
Sent: Tuesday, December 22, 2020 4:26:21 PM
Subject: Fwd: For approval: MCP Final Report Ember
Hello,

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From: "Snezhana McIver" <smciver@ptac.org>
Cc: "Marc Godin" <marc.godin@portfire.com>, "ssharma" <ssharma@ptac.org>
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Please reply by December 18 if you approve the final report for publication and payment of the final invoice.

Thank you,

Snezhana McIver  |  Direct: 587-891-9974

PTAC Petroleum Technology Alliance Canada  |  www.ptac.org
If you feel confident they have completed the work accordingly please go ahead and make the final payment.
Thanks,
Monica
I hope this email finds you well.

I am just following up in regards to the below email, as we require your approval to proceed with payment.

Thank you,
Snezhana

From: "Snezhana McIver" <smciver@ptac.org>
Cc: "ssharma" <ssharma@ptac.org>, "Marc Godin" <marc.godin@portfire.com>
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Snezhana McIver | Direct: 587-891-9974

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