E0161284

HEIDELBERG MATERIALS

LEHIGH EDMONTON ALTERNATIVE LOW CARBON FUEL PROJECT

FINAL OUTCOMES REPORT

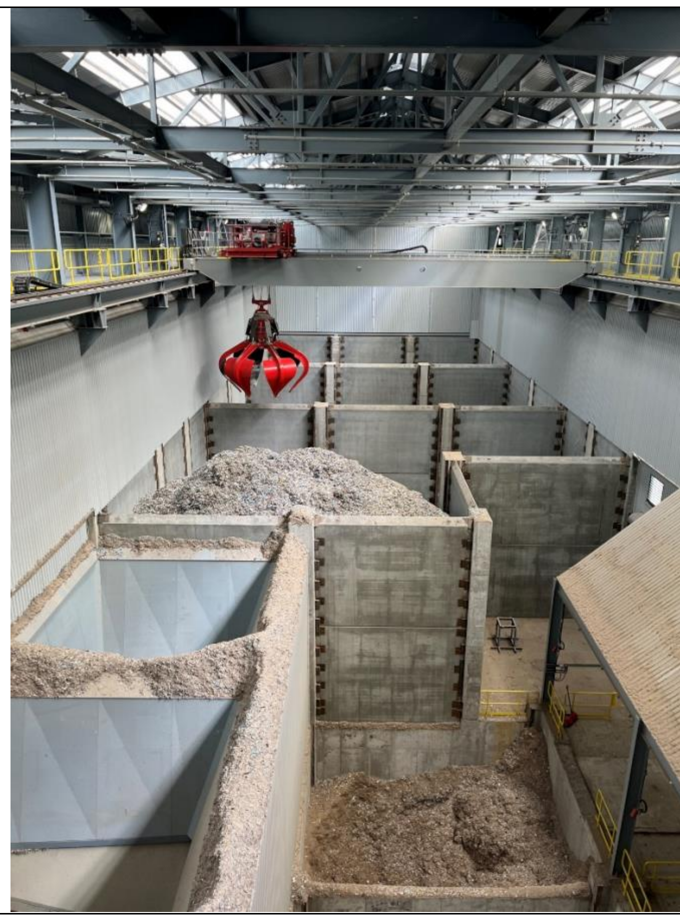
NON-CONFIDENTIAL

FINAL OUTCOMES REPORT (NON-CONFIDENTIAL)

Note: ***** indicates confidential redacted information throughout this report.

1.0 PROJECT INFORMATION

1. ERA PROJECT ID #	E0161284
2. CALL / ROUND	Shovel Ready Challenge
3. PROJECT TITLE	Lehigh Edmonton Alternative Low Carbon Fuel Project
4. COMPANY NAME	Heidelberg Materials Canada Limited (formerly Lehigh Hanson Materials Limited)
5. PROJECT TYPE (R&D, Development, Demonstration, Implementation)	Implementation
6. LOCATION (primary location the project took place by address, land description, or GPS coordinates)	12640 Inland Way NW, Edmonton, AB
7. PROJECT START DATE	June 21, 2021
8. PROJECT COMPLETION DATE	November 30, 2024
9. TECHNOLOGY READINESS LEVEL (TRL) AT PROJECT INITIATION	TRL 8
10. TRL AT PROJECT COMPLETION	TRL 9
11. JOBS CREATED	4 (estimated)
12. GHG EMISSIONS REDUCED (Project-level: annual, cumulatively by 2030 and by 2050)	Annual: 25.6 ktonnes (average for period 2025-2030 – this will vary with production) Cumulative by 2030: 153.5 ktonnes (dependent on production) Cumulative by 2050: 728.5 ktonnes (dependent on production)
13. TOTAL ERA FUNDING	$2,343,429
14. TOTAL PROJECT VALUE	$*****

15. ERA PROJECT ADVISOR	Mohammad Chowdhuri
16. SUBMISSION DATE	April 15, 2025
17. KEY PROJECT CONTACT NAME AND EMAIL	Jasper van de Wetering j.wetering@heidelbergmaterials.com
18. QUOTE	ERA funding support contributed significantly to advancing this capital-intensive Project from TRL8 to TRL 9.
19. NOTABLE COMMUNICATIONS	Heidelberg Materials issued a press release announcing completion of the Project on November 14, 2024. That press release is embedded here: PDF Edmonton_Alt_Fuels_Nov_14_2024.pdf
20. IMAGE (please insert or link a photo capturing the technology for ERA publications)	

2.0 TABLE OF CONTENTS

3.0 LIST OF TABLES

4.0 LIST OF FIGURES

5.0 EXECUTIVE SUMMARY

Project Implementation:

The Lehigh Edmonton Alternative Low Carbon Fuel Project, executed by Heidelberg Materials Canada Limited, aimed to reduce greenhouse gas (GHG) emissions by integrating waste-based alternative low carbon fuels (ALCF) into the cement kiln system at the Edmonton plant. The project involved several key phases:

- Engineering Design: Detailed planning and design of systems to handle ALCF:

- Construction and Commissioning: Building and commissioning infrastructure, including receiving, storage, reclaim, screening, conveying, and dosing/metering systems.

- Operational Performance: Utilizing the installed systems to feed ALCF to the kiln while manufacturing portland cement clinker.

Technology and Outcomes

The project advanced the technology readiness level from TRL 8 to TRL 9, demonstrating the feasibility of using ALCF at a commercial scale. The project achieved significant GHG emissions reductions and environmental benefits:

- Direct GHG Emissions Reductions: Annual reductions of 25 ktonnes, cumulative reductions of 153 ktonnes by 2030, and 729 ktonnes by 2050.
- Cost Savings: The project demonstrated cost savings of $***** million during the performance measurement period.
- Environmental Compliance: Emissions testing results were compliant with permit targets.

Environmental Benefits

The project contributed to environmental sustainability by:

- Reducing Methane Emissions: Diverting waste from landfills, thereby reducing methane emissions
- Lowering Fossil Fuel Extraction: Reducing the need for fossil fuel extraction and associated environmental impacts.
- Promoting Circular Economy: Utilizing waste materials as fuel, promoting sustainable waste management practices.

Technology Description and Impact

Game-Changing Technology

The technology involves using waste-based alternative low carbon fuels (ALCF) to replace fossil fuels in cement production. This approach is a game changer because it:

- Reduces GHG Emissions: ALCF contains biogenic carbon, resulting in "carbon neutral" CO_2 emissions when combusted.
- Utilizes Waste: Diverts waste from landfills, reducing methane emissions and promoting sustainable waste management.
- Economic Benefits: Reduces fuel costs and generates savings from avoided emissions credits.

Objectives and GHG Emissions Reduction

The primary objective of this technology is to reduce GHG emissions in cement production by replacing fossil fuels with ALCF. The technology achieves this by:

- Replacing Fossil Fuels: ALCF emits significantly less CO_2 per unit of energy compared to fossil fuels.
- Avoiding Methane Emissions: Diverting waste from landfills reduces methane emissions.
- Reducing Fossil Fuel Extraction: Lowering the need for fossil fuel extraction and processing.
  Target Customers

This project highlights the potential for significant environmental and economic benefits through the adoption of alternative low carbon fuels in industrial processes.

6.0 PROJECT DESCRIPTION

6.1 INTRODUCTION

The Project installed systems and infrastructure to receive, store, and feed waste-based alternative low carbon fuels (ALCF) to the cement kiln system installed at the Heidelberg Materials portland cement manufacturing plant in Edmonton, AB.

The Project involved engineering design, construction, and commissioning phases, followed by an operational performance phase. The first phase of the Project started on June 21, 2021, and ended on April 30, 2024. The second (operational) phase started on May 1, 2024, and ended on October 31, 2024.

The systems and equipment that were designed, constructed, and commissioned in Phase 1 included:

1. Receiving and unloading station: The receiving and unloading system was built to handle up to 20 deliveries, or 500 tonnes per day of ALCF. The receiving/unloading station was designed and built so that trucks can unload as quickly and efficiently as possible and the process was automated to the extent possible. The receiving/unloading station also transfers ALCF to the storage/reclaim system.

Figure 1 Storage Hall Unloading Area

Figure 2 Unloading Pit

2. Storage: A 6,600 cubic metre storage system was built to store enough ALCF for about 3 days worth of operation. The storage building was constructed out of concrete. The building has separated compartments to allow either segregation, or blending, of different types of ALCF. Computerized processes were installed to control which compartment the different types of ALCF are placed in.

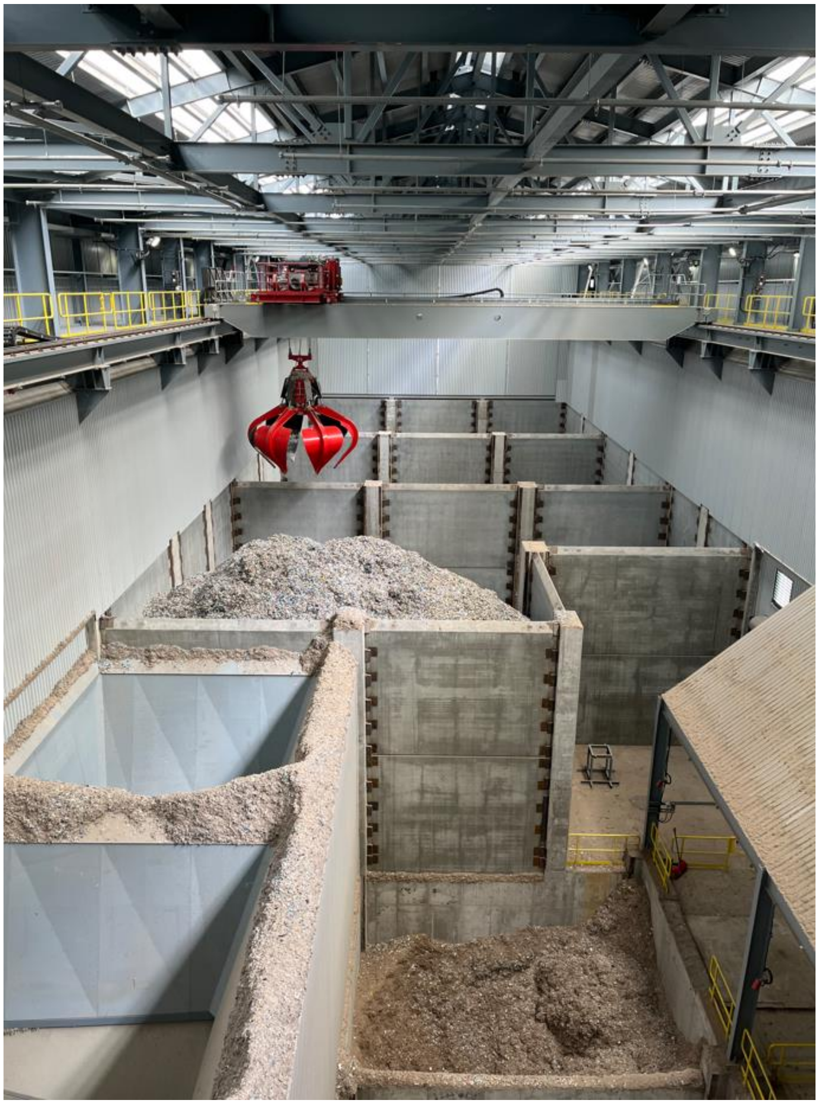


Figure 3 Storage Hall Indoors

3. Reclaim system: The reclaim system was installed so that ALCF can be extracted from storage and blended in a controlled manner, ensuring that a suitably blended stream of ALCF is directed to the kiln system with a consistent heat value critical to maintaining steady kiln operation. A crane system was utilized for this purpose. ALCF is extracted from storage onto a drag conveyor which directs ALCF through a screening tower.

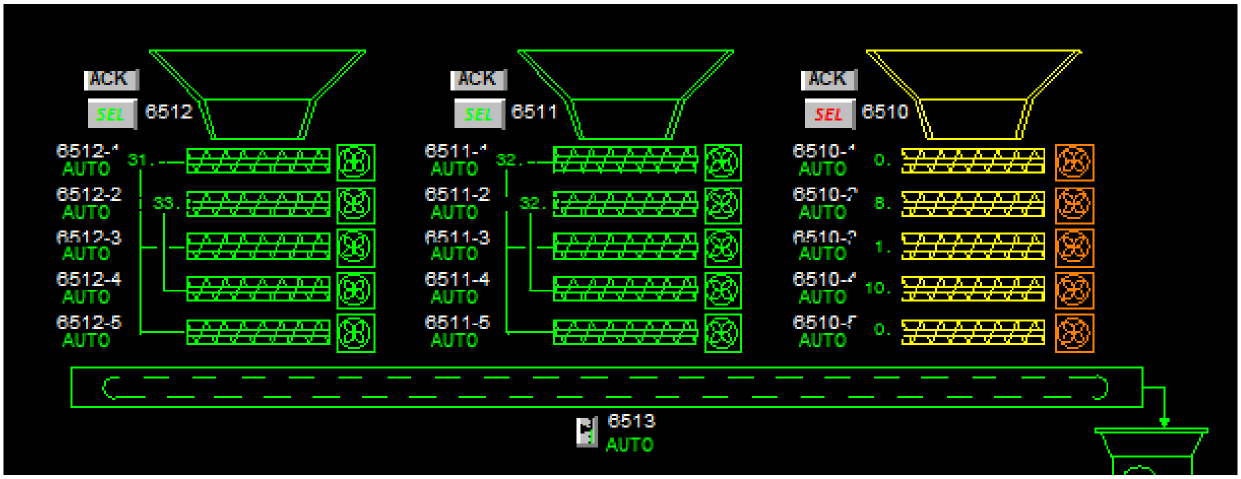


Figure 4 MultiBins Dosing System DCS Perspective

Figure 5 Hoppers for MultiBins

4. Screening tower: In the screening tower, ALCF passes through a de-agglomerator, past a magnetic drum, and finally through a disc screen. Once through the screening tower ALCF is fed onto a tube conveyor to the dosing/metering system located in the preheater tower of the kiln system.

Figure 6 StarScreen Inside Screening Tower

Figure 7 Stars Inside StarScreen

5. Tube Conveyor: The tube conveyor is similar to a conventional belt conveyor except that a mechanism curls the belt into a closed tube shape to prevent spillage and protect the material as it is being conveyed. The installed tube conveyor is approximately 330 metres in length.

Figure 8 Tube Conveyor System - Photo from Google Earth

6. Dosing/metering system: The dosing/metering system injects ALCF into the kiln system at a precise and consistent rate as prescribed by the kiln operator or automated kiln control system. The twin-screw design of the weighfeeder acts as an airlock to prevent hot gasses from the kiln system entering the ALCF feeding systems. The weighfeeder is designed to feed ALCF into the calciner vessel of the kiln system at a rate of 12 – 17 tonnes per hour.

Figure 9 MultiFlex Dosing System - Precalciner

In the operational phase, the systems installed during phase 1 were used to feed ALCF to the kiln system while manufacturing portland cement clinker.

6.2 BACKGROUND OF THE PROJECT

Heidelberg Materials Canada Limited operates a Portland cement manufacturing facility in Edmonton, AB. This facility uses a rotary kiln system to process raw minerals into clinker, the primary and active ingredient of Portland cement. Portland cement is a mineral binder used in the production of concrete, a durable building material for construction. Before the implementation of the Project, the cement kiln at the Edmonton plant was heated using natural gas and coal.

Globally, cement manufacturers like Heidelberg Materials use Alternative Low-Carbon Fuels (ALCF) to partially replace fossil fuels like coal and natural gas. This is because ALCF reduces Scope 1 greenhouse gas emissions and is generally more economical. ALCF reduces greenhouse gas emissions because it contains biogenic carbon that, when combusted, results in “carbon neutral” CO_2 emissions. Additional GHG reductions occur when waste used to produce ALCF is diverted from landfills, thereby avoiding methane emissions, and from reduced fossil fuel extraction and processing activities.

In 2018, Heidelberg Materials identified an opportunity to receive Refuse Derived Fuel (RDF) made from residential waste. This supply was sufficient to provide approximately half of the ALCF required to meet Heidelberg Materials’ objectives. Heidelberg Materials subsequently identified opportunities to work with local tire recyclers and construction and demolition waste managers to produce the remainder of the ALCF required. A decision was made to pursue funding to install the systems and infrastructure needed to receive, store, and feed ALCF to the kiln system.

Additional sources of ALCF were developed and secured while phase 1 was in progress.

6.3 PROJECT OBJECTIVES

Project objectives from original Contribution Agreement included:

1. Design, procure and install systems and infrastructure to receive, store, blend, convey, and inject ALCF into the Edmonton kiln system;

2. Successfully receive, store, blend, convey, and inject ALCF into the Edmonton kiln system at an operational scale to supply 30% of the heat required;

3. Maintain steady-state kiln operation while injecting ALCF as a direct fuel replacement; and

4. Maintain clinker quality to Lehigh standards while leveraging ALCF as fuel.

There were no evolutions or revisions made to the objectives over the course of the Project.

6.4 PERFORMANCE/SUCCESS METRICS IDENTIFIED IN THE CONTRIBUTION AGREEMENT

Table 1: Performance/Success Metrics per Contribution Agreement

Success Metric	Project Target	Project Achievement	Explanation
System Uptime (reliability).	> 50% uptime of ALCF system uptime while kiln is operating.	82% ALCF uptime achieved while kiln was operating (May 1, 2024 – October 31, 2024)	The success metric was achieved.
ALCF Replacement Rates	Steady state operation at 30% replacement achieved.	Steady state operation at 30% replacement achieved 30 days out of 175 operating days (May 1, 2024 – October 31, 2024). A replacement rate of 20.0% was achieved for the full operating period of 2024 (May 1, 2024 – December 31, 2024)	The success metric was achieved.
Environmental Compliance	Exhaust gas quality while using ALCF 100% compliant with permit	Two comprehensive emissions tests were completed while using ALCF and results were compliant with permit and equivalent to historical performance.	The success metric was achieved.
Economics	Demonstrate cost savings at Edmonton plant while using ALCF at 30% replacement compared to business as usual	Achieved: cost savings of $***** Million were achieved during the performance measurement period, not including revenue from the future sale of avoided emissions credits.	The success metric was achieved.

No evolution or revisions to the performance/success metrics were made over the course of the Project.

6.5 PROJECT CHANGES

There were no changes in the Project or corporate structure during the lifecycle of the ERA funded Project scope. There was however a change in corporate identity. In January 2023, the HeidelbergCement Group became Heidelberg Materials, and this new brand identity was applied at all levels of the global organization, including the Western Canadian operations which were formerly known as Lehigh Hanson Materials Limited.

Heidelberg Materials will be used throughout this report to also mean Lehigh Hanson and/or Lehigh Hanson Materials Limited.

6.6 TECHNOLOGY RISKS

No challenges arose that were not also identified as risks when the Final Project Proposal was prepared. A discussion of those risks follows:

Table 2 Discussion of Technology Risks

Key Risks	Prob.	Impact	Risk	Risk Mitigation and Response Strategy
Technical				
Disruption of kiln process from buildup and reducing conditions	M	M	M	Continuous monitoring of processes and fuel quality. Development of automated and manual processes to avoid and manage buildup.
Disruption of kiln process from inconsistent fuel quality.	M	M	M	Development and constant improvement of fuel quality monitoring blending processes. Active engagement with suppliers to improve their quality and process control systems.
Disruption of kiln process from blockages in feed systems	L	M	L	Thoughtful design of feed systems and transfer points. Application of good maintenance practices.
Result: Short-term fluctuation of ALCF flow through the feed system was experienced during the operational performance phase (May 1, 2024 through October 31, 2024) of the Project. This ALCF feed fluctuation was correlated with “spiking” of CO within the kiln system, but no material disruption to the kiln process and no buildup issues were observed as a result. A root cause analysis of the flowability issue was performed and a root cause(s) were identified. The equipment supplier will be making significant changes to the design of the weighfeeder in April 2025 during the annual plant maintenance shutdown which will resolve the issue. In addition, the control logic that varies the speed of the tube conveyer was modified to better maintain the level of ALCF in the weighfeeder surge bin. Short term- inconsistencies of ALCF quality were observed during the Project operating period, primarily with respect to moisture (and heat value) and over-sized particles. The heat value quality fluctuations were accommodated by the kiln control system which automatically adjusts the natural gas balance fuel and disruption of the kiln process was not observed. Large particles of materials such as wood and rigid plastic were removed by the installed star screen system and did not cause operational issues because they were not fed to the kiln				

system. Large particles of flexible plastic such as plastic bags however wrapped around the rotating shafts of the star screen and reduced the amount of "on-spec" ALCF that reached the kiln system. Neither of these oversized particles impacted the kiln process but rather they increased the amount of ALCF rejected. All quality inconsistencies were documented and presented to suppliers and work is ongoing to minimize their frequency of occurrence.				
Commercialization & Market Adoption				
Instability or disruption of ALCF supply chain.	L	H	M	Long term contract with stable committed suppliers. Maintain relationships with additional alternative suppliers. Ensure offtake is consistent and low-cost relative to alternative disposal methods.
Result: The project was designed to use a blend of three types of ALCF, MSWRDF, C&DRDF, and Tire Fibre. The supply of MSWRDF and Tire Fibre met expectations but the primary supplier of C&DRDF faltered soon after the system was started primarily due to cost of transportation from their site in southern AB to the cement plant in Edmonton. Three alternative supplies of C&DRDF have been identified and are being developed and the supply of C&DRDF is expected to meet demand starting in November of 2024.				
Regulatory & Permitting Risks				
Construction permits	L	H	M	Permit requests will be made in a timely manner. Lehigh as not identified any reason why building permit requests would be denied or delayed.
Emissions not compliant with permit	L	M	M	Stack emissions testing while using ALCF is required by operating permit. Exhaust gas quality has been confirmed during demonstration trials and plant operated within compliance limits.
Result: No issues with obtaining construction permits were experienced. Two stack emissions tests were caried out during the Project operating period and in both cases measured stack emissions were compliant with the Edmonton plant Approval and consistent with performance prior to implementation of the ALCF Project.				
Project Plan & Timelines				
COVID	H	M	H	Impact to engineering, equipment delivery and construction schedule, due to limited site visits, potential fabrication/shipping delays and additional safety precautions required during installation and commissioning. Mitigation will be to monitor progress closely and address items as they arise, while building flexibility into our engineering, delivery, and construction schedules.
Weather	M	M	M	The current schedule details final installation and commissioning during the winter months. Mitigation will be to have a detailed construction

				schedule that will address anticipated weather issues that will impact work productivity based on past project experiences.
Result: Significant delays in the Project schedule were experienced due to the COVID emergency. The delays impacted all major aspects of the Project including, fabrication, shipping, access to construction labor and equipment. The original proposed Project end date of March 31, 2024 was ultimately revised to November 30, 2024. With respect to weather, an extreme cold weather event in December 2023 caused a major and quite extraordinary kiln shell failure which delayed the kiln startup (and the start of the operational performance period) from January 2024 until May 2024. The kiln system was stopped at the time for a winter inventory control outage at the time and the failure was entirely unrelated to the ALCF Project. The Project end date was not extended because of this event, but rather the operational performance period was shortened.				
Budget & Cost Uncertainties				
Budget	M	M	M	Availability and order placing timing for vendor and contractor orders to be finalized upon approval of funding. Mitigation will be to work with multiple vendors and contractors prior to selection.
Result: The Project budget came under pressure very early in the process. Refinement of the Project budget during the design phase of the Project resulted in an increase of the total cost estimate from $***** to $*****. The, during Project implementation, impact from the COVID pandemic and a requirement to install more sophisticated fire suppression systems that expected increased the final Project budget to $*****. The final cost of the Project was $*****. Relief to the increased budget came when the Government of Alberta agreed to provide a $***** funding to Heidelberg Materials as part of the "Industrial Energy Efficiency and Carbon Capture, Utilization and Storage (IEE-CCUS) Grant Program. Receipt of those funds however resulted in reduction of funding from ERA from the originally agreed $11.7 to $2.3M to ensure total Government funding did not exceed 85% of the original Project budget of $*****. All told, Heidelberg Materials contributed $***** of its own funds toward the Project.				
Financing				
None identified	L	L	L	No risk identified
Result: Internal financing was approved despite the significant increase in Project cost.				
Team/Management/Partnership Risks				
Team member availability	M	L	L	Travel restrictions for team members and consultants due to COVID. Additional virtual meetings will be planned, along with support from team members who will be on site (plant personnel).

Result: No delays specific to travel restrictions were experienced. All necessary travel was approved by the various jurisdictions involved where necessary and virtual meetings were used in place of travel where appropriate.

7.0 PROJECT WORK COMPLETED AND OUTCOMES

7.1 METHODOLOGY

The Project was carried out using procedures and Project Management methodology typical for a mechanical/electrical and construction project of this scope and size. Key aspects of those activities are described below. Refer also to section 8.2.

7.1.1 Organization Chart

*****

Figure 10 Organization Chart

7.1.2 Engineering

Industrial Ally was the engineer of record for the civil and structural components of this project. Industrial ally was also hired through Schenck to design the conveyor support structures. BCS was the engineer of record for the electrical design. Schenck did the engineering for the main process equipment, chute work and conveyor supports. Tairec consulting was the engineer of record and represented HM for the fire suppression design. RotaFlow did in house design related to the fire suppression system and provided stamped drawings for the more detailed aspects of the design. TWS Engineering was the engineer of record for the truck scale and bypass feeder.

Industrial Ally was selected as the engineering and construction services provider. Cinar Limited based out of the UK was awarded in Nov 2021 to work on CFD modelling for the Edmonton kiln process to determine the injection point of ALCF into the calciner. Explosion testing was completed for the three ALCF materials in November 2021. All major engineering was completed in 2nd quarter 2022. PSCL was hired to automate the fuel receiving, weighing and unloading into the storage hall. An RFID system was installed to automate the process.

7.1.2 Equipment Supply

Proposals for the main process equipment supply were received from four vendors, and a Document of Vendor Selection (DOVS) was issued on 4 November 2021. The Steering Committee (SC) approved the finalization of negotiations with Schenck. The cost of Schenck equipment exceeded the budget established in October 2020 by approximately 20%. This increase was attributed to higher steel costs for the tube conveyor supports and increased shipping costs. On 23 November 2021 and agreement was reached with Schenck Process to begin equipment engineering and design work.

Simo crane delivery was identified as the critical path due to long lead time and due to supply chain issues and shipping delays. Partial Schenck approval drawings were received on 1 Feb 2022. Crane bypass system equipment contract was finalized in December 2022. Engineering was completed in fast phase manner and the equipment delivery for the crane bypass system started and completed in 2nd quarter 2023.

Crane bypass system commissioning was planned for June 2023. The fire suppression system was not ready for that. As a result, a chemical powder based Tungus system was installed. RotaFlow was contracted to supply and install the fire suppression system.

There were several supply chain issues as a result of the pandemic. The Simo overhead crane, initially scheduled for delivery in September 2022, arrived in July 2023. Schenck, our primary AF equipment supplier, had significant delays, and expediting deliveries was challenging despite liquidated damages for delay. Suppliers refused to guarantee delivery dates or assume fixed-price freight and shipping costs. The prices and manufacturing times for electrical equipment surged. Additionally, contractor backlogs due to pandemic-related work stoppages led to premium pricing post-COVID restrictions.

7.1.3 Construction

Field work began on October 4, 2021, with an underground utility survey. Geotechnical drilling finished in the week of October 25, 2021. Caisson installation started and ended in the third quarter of 2022. Civil construction by PCL began in September 2022 and finished by early 2023. PCL had issues managing subcontractors, especially for earthworks. There were errors with embedded items in foundations, and installing rebar and plates proved difficult, leading to extra costs. Some anchor bolts needed epoxy injection after foundation curing. PCL was delayed by ~40 days due to winter weather and the complexity of the concrete reinforcing. The PCL claim for this delay was negotiated down from CAD 259K and settled at CAD 120 K. This claim was paid due to the complexity of installing the reinforcement rods and embed plates. There were additional expenses due to structural backfill and other miscellaneous issues. Norstar did the truck scale construction. Weather delay also delayed the downstream contractors such as Stratus and Waiward.

Waiward handled the structural and mechanical aspects of the project. Subcontractors to Waiward managed the architectural work, HVAC, crane services, overhead doors, and the compressed air package. Some fabrication errors in the steel were identified upon receipt at the site. Having a local fabrication shop was advantageous for production and resolving any issues. The Waiward contract included a union labor wage escalation risk that was limited to CAD 418K through end-May 2023 as per the contract negotiations. This risk management helped reduce the cost escalations.

Figure 11 Overview of Project – Photo from Google Earth

7.1.4 Electrical/Automation

The Edmonton AF system comprises approximately 60 motors, 20 VFDs, and 900 I/O points. A new 1000 kVA MV/LV substation was added to provide power to the automated crane and the Schenck MultiBin feeders in the AF building storage. A new electrical room (ER) was constructed to house the new MV/LV substation, MCCs, I/O panels, and other equipment installed in the AF building. Additionally, a new MCC and I/O panel were installed in an existing electrical room at the base of the Preheater tower to supply power to the Schenck MultiFlex feeder and the TEDO belt.

Figure 12 Electrical MCCs - Photo from Google Earth

Cameras were installed in the AF storage hall, around the screen, and at the unloading stations. Comprehensive fire alarm and protection systems were also implemented in the Storage Hall and Preheater. A diesel-driven fire pump was installed for the Storage Hall fire suppression due to the high demand that an electrically driven fire pump would place on a new large diesel emergency generator. The electrical fire pump in the Preheater tower was connected to an existing diesel emergency backup system.

The existing plant Unison Distributed Control System (DCS) was expanded to control the AF system. A full replacement of the plant DCS was not considered due to cost and schedule constraints. The DCS, which was developed by Process Solutions over 30 years ago, relies on obsolete Rockwell Automation (RA) PLC 5 hardware, which is no longer available from RA. Refurbished and guaranteed PLC 5 parts sourced from the secondary market by BCS were installed in new I/O panels. Smart MCCs, which would be compatible with an up-to-date process control system, could not be selected with the Unison DCS. Ethernet communications with VFDs and starters with smart overloads would have provided enhanced diagnostics and expedited electrical installation. As a result, standard MCCs with hardwired controls were utilized. The PLC software was successfully developed by the local plant automation team.

7.1.5 Permitting

The Operating Approval from Alberta Environment and Parks was amended in the second and third quarters of 2021 to permit the use of three generically classified alternative fuels: RDF, CDRFD, and Tire Fibre. Major development permit was approved by City of Edmonton in May 2022. Building and commercial final permit were obtained from City of Edmonton in August 2022.

For the expanded construction permit to allow construction to continue beyond foundations, the City of Edmonton required that the drawings need both a P. Eng seal and Permit to Practice (in Alberta) seal. Whereas the former requirement was always known, the latter was not and was pursued by the affected design teams (Industrial Ally and BCS, along with their respective sub-consultants (rCon for IA and Magna IV for BCS). This required that they apply for a business license in the province of Alberta and then apply for the associated Permit to Practice. This work was completed with additional effort by sub-vendors of the engineering partners and additional cost.
The Edmonton Fire Department inspected the dry hydrant at the pump building and required minor modifications, which were completed. They also conducted a flow test and found it insufficient for their fire trucks. As a result, HM's fire consultant, Tairec, had to increase the size of the storage hall fire suppression system pump.

7.2 TECHNOLOGY DEVELOPMENT

Commissioning and Startup

A detailed commissioning plan was developed to facilitate commissioning. This document outlined the processes, activities and schedule to take the project from construction to the turnover to the hot commissioning team, with the end goal of transferring ownership and operation of the equipment to Edmonton plant personnel.

7.2.1 Cold commissioning checks

Three tag-coded check-out systems for mechanical, electrical and group run/interlock testing were used for cold commissioning.

1. MANILLA TAG was assigned once the equipment had been mechanically checked out

2. BLUE TAG Indicated that the equipment had been electrically checked out

3. RED TAG: was added to the MCC bucket when the equipment had successfully fulfilled the group start and all interlocks were functioning

Pre-commissioning electrical checks included wire checking and insulation resistance measurements. After mechanical checks were complete, rotation checks and no-load voltage and current readings were taken on motors. Local jog and remote PLC checks were made. Local disconnects were deactivated to prove the not-ready status. Data was recorded on a check-out sheet. Signatures from responsible parties verified the actions recorded on the check-out sheets.

Commissioning was a joint effort with all parties including Heidelberg Materials personnel, Schenck, Simo, Beumer, RotaFlow and various subcontractors. After the pre-commissioning checks were completed, the group inter-locking and group starts were made. After the dry runs were completed, product runs commenced

Cold commissioning began on June 23, 2023, followed by hot commissioning of the crane bypass system on August 21, 2023. Initial trials showed variations in alternative fuel feed rates and natural gas consumption. The AF feed rates were gradually increased, and the system achieved a 24-hour operation on September 26, 2023.

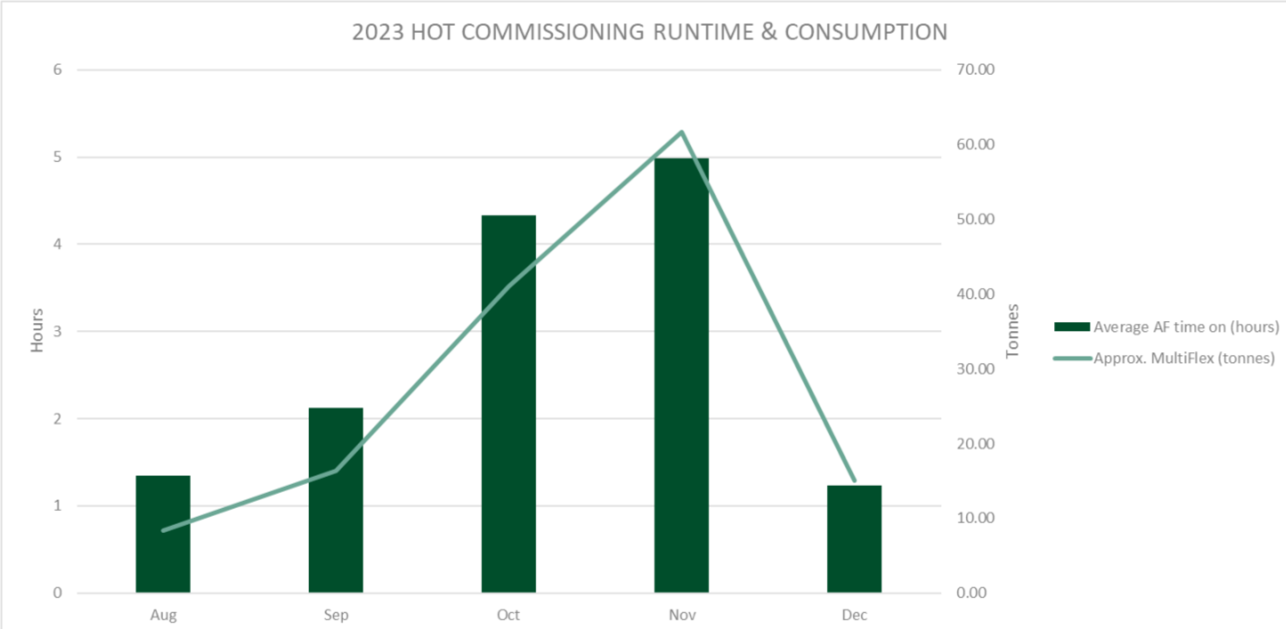


Figure 13 2023 Hot Commissioning Runtime & Consumption

7.2.2 Hot commissioning and Process Impact

The process impact of integrating alternative fuels (AF) in the Edmonton cement kiln was carefully monitored and adjusted throughout the project. The primary goal was to evaluate how the introduction of AF, specifically RDF (Refuse-Derived Fuel) and CDRDF (Construction Demolition RDF), affected kiln operations, emissions, and overall fuel efficiency.

Combustion Optimization

• Increased Oxygen Levels: The introduction of alternative fuels necessitated an increase in oxygen levels to ensure complete combustion. This was achieved by adjusting the kiln's induced draft (ID) fan speed.

• Kiln ID Fan Speed: Adjusting the speed of the kiln ID fan was crucial to manage the air flow and maintain optimal combustion conditions. By fine-tuning the fan speed, operators could ensure that sufficient oxygen was available for the alternative fuels, which have different combustion characteristics compared to natural gas.

• Reduction of CO Spikes: Proper adjustment of the kiln ID fan speed helped in minimizing the occurrence of carbon monoxide (CO) spikes, which are indicative of incomplete combustion. CO spikes were initially a challenge due to the inconsistent burn-out of AF, but were reduced as the blending ratios and oxygen levels were optimized.

Blending Ratios of RDF and CDRDF

• Blending Ratios: The blending ratio of RDF to CDRDF was a critical factor in optimizing combustion. Initially, various ratios were tested to identify the most effective combination for complete fuel burn-out.

• Optimal Ratio: A 50/50 blend ratio of RDF to CDRDF was found to be optimal. This blend provided a balance between calorific value and biomass content, ensuring consistent and stable combustion without excessive CO emissions.

7.3 PROJECT ACHIEVEMENTS, RESULTS, AND ANALYSIS

The project resulted in the construction and commissioning of a full-scale automated system to receive, store, and feed alternative low-carbon fuels (ALCF) to the Heidelberg Materials Edmonton cement plant rotary kiln system.

The project achieved all performance objectives set for the commissioning and initial operational phase:

- 82% uptime during the operational period, compared to a target of 50%.
- The target rate of 30% ALCF replacement was achieved for 30 of the 175 days during the operational period.
- Emissions testing results while using ALCF were compliant with permit targets and equivalent to historical performance without using ALCF.
- Cost savings of $***** were achieved during the 175-day operational period, excluding future sales of GHG performance credits.

Commercial operation will require resolving challenges identified during the commissioning and operational phases, including increasing the rate of ALCF to 50% and reducing or eliminating CO spiking caused by ALCF feed fluctuations and consistency.

Figure 14 Example of CO Spikes 2024

Figure 15 Example of Post-Process Changes to Address CO Spikes (amplitude significantly lower)

A root cause analysis of the CO spiking and flowability issues was performed, and the root causes were identified. The equipment supplier will make significant changes to the design of the weighfeeder in April 2025 during the annual plant maintenance shutdown to resolve the issue. Additionally, the control logic that varies the speed of the tube conveyor was modified to better maintain the level of ALCF in the weighfeeder surge bin.

Short-term inconsistencies in ALCF quality were observed during the project operating period, primarily concerning moisture (and heat value) and oversized particles. This may have also contributed to CO spiking. Given the nascence of the ALCF market in Alberta, this is not surprising, and Heidelberg Materials staff are working closely with suppliers to resolve these issues.

Despite the CO spiking, it should be noted that kiln operation was steadier than expected, and that fluctuations in heat input was well handled by the automated kiln control system which counter-fluctuated the natural gas inputs as necessary.

Regarding ALCF supply volume as it affects the 50% replacement objective, Heidelberg Materials has been successful in securing ample supply as of Q1 of 2025, particularly with respect to high biomass Construction and Demolition waste-based fuel.

8.0 LESSONS LEARNED

8.1 CHALLENGES

The Project faced several challenges that led to both delays and budget exceedances:

Global Supply Chain: The primary and significant challenge encountered in the execution of the project as planned is the impact on the global supply chain due to the COVID/Russia-Ukraine conflict. This has affected both the timing and budget of the Project. Skilled manpower has been extremely expensive to obtain and has delayed the project. Design of the fire suppression while meeting the safety requirements and meeting the code requirements has also been challenging.

Project Budget: The original project budget of $***** has also been challenged, primarily as a result of the global supply chain disruptions but also due to incomplete costing at the time that the funding application was made. The updated project cost estimate of $*****, which was reflected in the July 2023 agreement amendment, was ultimately exceeded by ****%. Total final project cost (including spending during the operational phase) was $*****.

Startup delay due to Kiln Shell Failure unrelated to Project: The plan to begin using ALCF in the kiln at a commercial (operational) scale in Q1 of 2024 was impacted by an unexpected and significant kiln shell failure that occurred during the extreme cold weather experienced in December 2023. Repairs to the kiln shell delayed the start of the operational phase, but not the duration. A certain amount of downtime was expected to occur later during the operational phase anyway, but this downtime was eliminated (shifted) as a result of the kiln shell repairs.

Commissioning at Scale**:** On startup at scale in May 2024, the Project experienced fuel flow inconsistencies through the dosing system at the kiln inlet. This caused CO spikes in the kiln system and limited the maximum replacement rate. Various strategies were used to improve flow, with some success, but ultimately the vendor agreed to replace the main body of the dosing system with a different design that is expected to resolve the issue permanently. The redesigned system will be installed during the 2025 plant maintenance shutdown, scheduled for April 2025.

ALCF Supply disruption: The project was designed to use a blend of three types of ALCF, MSWRDF, C&DRDF, and Tire Fibre. The supply of MSWRDF and Tire Fibre met expectations but the primary supplier of C&DRDF faltered soon after the system was started primarily due to cost of transportation from their site in southern AB to the cement plant in Edmonton. Three alternative supplies of C&DRDF

have been identified and are being developed and the supply of C&DRDF is expected to meet demand starting in November of 2024.

8.2 PRACTICAL LEARNINGS

A summarized version of the lessons learned from the Edmonton AF project:

• Sufficient time and budget are needed to perform an adequate level of preliminary engineering and obtain major equipment supply and construction erection/installation proposals before a budget estimate is advanced for authorization. This standard protocol was not followed to support a public funding application deadline. Further, the same estimate was used for Cross-Area Funding consideration and AFE authorization. The budgeting process takes time to engage and then manage a consulting engineer, and develop sufficient documents (flow sheets, equipment list, site plan, general arrangements, one-line, etc.) for use in tendering for equipment, followed by tendering for construction proposals. The complexity of the project dictates the time required.

• Without tendering for construction proposals, historical unit cost rates were used for estimating the construction cost. The historical unit rates did not anticipate the lingering effects of pandemic-era pricing and the contractors' unwillingness to restore pricing to pre-pandemic pricing.

• There was insufficient time to investigate the fire suppression requirements of the codes, City of Edmonton Fire Rescue, HM global standards, NAM Risk Management, and good practices before submitting the budget. Once the requirements were known late in the project, adverse cost and schedule impacts were inevitable.

• The cost estimate was prepared without the knowledge of when the project would be approved. Cost escalation based on the anticipated date of approval and market conditions should be incorporated into the budget.

• Additional scope deemed necessary during project execution such as the storage hall crane bypass system, an extensive fire suppression system and truck scale system should have been identified during a preliminary engineering phase.

• The existing Unison process control system had to be used in the new project to have smooth integration. This resulted in the sourcing and addition of a large quantity of obsolete ABB PLC parts. Communications with Schenck and SIMO panels had to be hardwired instead of Ethernet due to system limitations. It is hard to justify use of new control system when parts of the plant are upgraded. So long term plan has to be put in place for the old process control system.

• A positive lesson to be learned is that the project was able to successfully assemble a good site management team.

• The Edmonton plant engineer coordinated well with the various City of Edmonton departments to obtain the required permits and conditional permits to allow partial start-ups of the equipment as it was installed.

• The construction manager (consultant) had a very good construction background and provided detailed written reports and proactively documented site events to allow the project team to mitigate claims. His electrical background helped to reduce the need for controls commissioning support and the associated cost.

• The BCS commissioning team and plant automation team worked well together.

• The commissioning manager (consultant) had a very good process background in the pyro system. He developed operating protocols and procedures and trained the operators resulting in very efficient commissioning.

• Project safety was managed very well. No LTI or medical aid cases, with only 3 first aid cases. The site safety manager (consultant) was vey experienced and worked well with the project team and site contractors.

• Coordination between contractors was done well. They had good communication and smoothly managed issues between themselves.

• The plant operation and automation teams were integral parts of the successful commissioning.

• The Schenck-supplied equipment (e.g., SIMO crane, chain conveyor, MultiBins, TEDO conveyor, etc.) except for Multiflex has operated well to date with only minor issues experienced during commissioning. The SIMO and Schenck site support technicians were exceptional. The drum magnet works well by removing all of the metal from the material stream with no spillage. A drum magnet is recommended for this application over a cross-belt magnet. One MultiBin with lower volumetric flow rates and two MultiBins with higher volumetric flow rates allow for a large range of fuels (very high to low heat value) to be used. The MultiFlex discharge is 6m from the injection point to the calciner. There is no airlock other than the material sealing the MultiFlex screws. This arrangement has worked well. The high-temperature gate sees 20-50°C under normal operation and <100°C in upset conditions.

• Use of precast concrete wall panels versus cast-in-place walls went well, using lower-priced shop labor and preassembly versus higher construction cost site labor – and time. See Figure 13

• Cladding on the inside of the building works well to reduce material buildup. The cladding was installed on the storage side of the wall, thus avoiding build up of fuel on the wall ledge and potentially hazardous conditions.

• Precast wall ledges were v-shaped using angle iron to prevent having a flat surface that will buildup with fuel and cause potential spontaneous combustion. See figure 13.

• The main laydown area was identified earlier in the process and was managed very well logistically. This helped in pre-assembly as well as less congestion in the construction area.

• Edmonton's construction contractors continue to be very selective in projects they undertake and at prices that are appreciably higher than elsewhere in NAM. This needs to be better considered in the construction cost.

• Quality control was managed well by the main contractors. All the contractors selected for the work were well-qualified resulting in a high-quality product.

• All major contracts were awarded to the contractors with the lowest priced, technically complete proposals and all contracts included liquidated damages for delay. With very tight margins, each contractor was extremely aggressive in submitting delay claims to gain margin or to offset potential assessment of LD(s). This consumed a vast amount of CCC project management time to quell the claims.

• Edmonton labor unions went through labor cost adjustment after many years in the middle of the project. So many of the contractors had a clause in their proposals to adjust the labor rates through the course of the project as and when the labor cost adjustment happened. To manage this risk, major contract such as the one with Waiward had a provision to limit the price adjustment to a maximum value. This helped since it turned out that the cost escalation would have been higher if not for this provision in the contract.

The overarching lessons include the necessity of thorough planning, clear specifications, realistic budgeting, and consideration of maintenance and safety in design to ensure project success and equipment longevity.

8.3 ORGANIZATIONAL LEARNINGS

Refer to section 8.2

8.4 HIGHLIGHTS

Refer to section 8.2

9.0 GHG BENEFITS

9.1 PROJECT BASELINE EMISSIONS

The baseline for the GHG reduction calculations was determined by aggregating relevant Edmonton facility data from 2017, 2018, and 2019. This period was chosen as best representing the operating conditions of the Edmonton facility between the 2020 (the year that the Project proposal was developed) and 2040. Notably, the facility used about equal amounts of coal and gas 2017, but it used predominantly natural gas in 2018 and only natural gas in 2019.

A facility specific baseline was used because an Alberta Industry baseline could not be calculated for confidentiality reasons. There are only two portland cement manufacturing plants located in Alberta. The plant in Edmonton is owned and operated by Lehigh Hanson Materials Limited which is part of the Heidelberg Cement Group. The Edmonton plant is the subject of this proposal. The second plant is located in Exshaw, AB and it is owned and operated by Lafarge Canada, which is part of Lafarge Holcim, a direct competitor to Heidelberg Cement. Because Lehigh and Lafarge are direct competitors, neither party can know the production or specific fuel consumption figures of the other for competitiveness and anti-trust reasons.

1) The Material Sources used to calculate emissions from the baseline phase include:

   a. Stationary combustion CO2 emissions from fuels which are combusted in the cement kiln system for the purpose of generating the heat required to calcine limestone and drive clinkering reactions.

2) Sources which were excluded from this project include:

   a. Industrial process (calcination) emissions that result when CO2 is liberated from CaCO3 and MgCO3 in the limestone used as the primary raw material input into the cement manufacturing process. Emissions from this source will not be affected by the project in any way.

   b. Emissions which result from the combustion of organic carbon which is assumed by protocol to exist in the raw mineral inputs used to manufacture portland cement clinker. Although this source is classified as stationary combustion according to the method prescribed by TIER and CCIR, the project will not affect emissions from raw materials.

   c. Emissions from mobile equipment used in the cement manufacturing process. These emissions are not significant and are not available for reductions by this project.

   d. Emissions of methane and nitrous oxides which occur as a by-product of fuel combustion in the kiln processes and methane from the storage of coal on-site. The difference between the methane and nitrous oxide emissions that occur when coal and natural gas is replaced by ALCF are not significant and have been ignored for the sake of simplicity.

   e. Emissions from the use of natural gas to heat one of the cement mills installed at Edmonton. These emissions will not be affected by the project.

f. Emissions associated with the electricity required to operate the cement manufacturing process. These emissions occur off site and are not available for reductions by this project.

3) There were no relevant Sinks in the baseline period.

Methodology: The Lehigh Edmonton facility is subject to Alberta's Technology Innovation and Emissions Reduction Regulation. As such, all emissions from the facility are calculated according to the "Alberta Greenhouse Gas Quantification Methodologies Version 2.1", published by the Government of Alberta in March of 2021.

Prior to being subject to TIER, the Edmonton facility was subject to the Carbon Competitiveness Incentive Regulation (CCIR) and before that the Specified Gas Reporting Regulation (SGRR). The relevant methods in above referenced TIER manual are equivalent to the methods prescribed for use under CCIR and SGER. These methods are described in the "Quantification Methods for the Carbon Competitiveness Incentive Regulation and the Specified Gas Reporting Regulation Version 1.4", published by Alberta Environment and Parks in March of 2020.

9.2 PROJECT EMISSIONS

The sources and methodology during the operational performance phase of the project were the same as those used during the baseline period.

9.3 EMISSIONS REDUCTION IMPACT

The Project results in direct GHG emissions reductions when ALCF is used in place of fossil fuels.

In the case of the Edmonton cement plant baseline, the kiln was fired using a 16.5% coal and 83.5% natural gas thereby emitting 62.1 kg CO_2/GJ of energy consumed.

Table 3 Derivation of baseline fuel emissions intensity

		A	B	C	D	E
		portion of fuel blend	heat value	carbon content	biomass content	CO2 intensity
		%	Net GJ/1000m3 & net GJ/tonne	tonnes C/ 1000m3 & tonnes C/ tonne	%	tonnes CO2e/netGJ
1	**natural gas**	83.5%	34.8	0.532	0.0	0.0561
2	**coal**	16.5%	18.1	0.458	0.0	0.0929
3	**Total**	-	-	-	-	**0.0621**

Where:
E1 = 3.664 * C1 * (1-D1) / B1
E2 = 3.664 * C2 * (1-D2) / B2
E3 = (A1*E1) + (A2*E2)

Carbon content of natural gas calculated using daily composition data provided by natural gas vendor (TC Energy) and carbon content of coal determined by historical third-party laboratory data.

The Project will partially replace fossil fuel with an ALCF consisting of 43.9% MSW RDF, 6.3% Tire Fibre, and 49.7% C&D RDF. This ALCF blend will emit 42.4 kg CO_2/GJ, based on % carbon and % biomass testing carried out in 2024 by third party laboratories in accordance with Alberta GHG Reporting Regulations.

Table 4 Derivation of ALCF fuel emissions intensity

		A	B	C	D	E
		portion of fuel blend	heat value	carbon content	biomass content	CO2 intensity
		%	net GJ/tonne	tonnes C/ tonne	%	tonnes CO2e/net GJ
1	**RDF**	43.9%	14.7	0.378	33.8%	0.0623
2	**TF**	6.3%	30.7	0.714	31.4%	0.0584
3	**CDRDF**	49.7%	14.1	0.390	78.7%	0.0216
4	**Total**	100.0%	15.4	0.405	56.0%	**0.0424**

Where:

E1 = 3.664 * C1 * (1-D1) / B1
E2 = 3.664 * C2 * (1-D2) / B2
E3 = 3.664 * C3 * (1-D3) / B3
E4 = (A1*E1) + (A2*E2) + (A3*E3)

Using ALCF in place of baseline fossil fuel therefore reduces GHG emission by 19.7 kg CO_2 per Gigajoule for every GJ of ALCF used and emissions reduction from the Project can be projected as follows:

Table 5 Projection of GHG reductions

		A	B	C	D	E	F	G
	Period	Substitution rate ALCF	clinker production	heat consumption	heat from ALCF	GHG intensity base fuel	GHG intensity ALCF	GHG reductions
		%	**tonnes**	net GJ/tonne	net GJ	tonnes CO2/net GJ	tonnes CO2/net GJ	tonnes CO2e
1	**2025**	**50%**	*****	*****	*****	0.0621	0.0424	23,893
2	**2026**	**50%**	*****	*****	*****	0.0621	0.0424	24,178
3	**2027**	**50%**	*****	*****	*****	0.0621	0.0424	24,574
4	**2028**	**50%**	*****	*****	*****	0.0621	0.0424	25,345
5	**2029**	**50%**	*****	*****	*****	0.0621	0.0424	26,760
6	**2030**	**50%**	*****	*****	*****	0.0621	0.0424	28,752
7	**2031-2040**	**50%**	*****	*****	*****	0.0621	0.0424	287,521
8	**2041-2050**	**50%**	*****	*****	*****	0.0621	0.0424	287,521

Where:

Gx = Ax*Bx*Cx*(Ex-Fx)

In the full year 2024, 20.0% of the heat required to make clinker was derived from ALCF. The composition of that ALCF however differed from the composition anticipated to anticipated for 2025 and beyond however, primarily because the supply chain for C&D RDF was still developing. Heat consumption was also lower than anticipated.

Table 6 Derivation of ALCF fuel emissions intensity for 2024

		A	B	C	D	E
	2024	portion of fuel blend	heat value	carbon content	biomass content	CO2 intensity
		%	net GJ/tonne	tonnes C/ tonne	%	tonnes CO2e/netGJ
1	**RDF**	56.3%	14.7	0.378	33.8%	0.0623
2	**TF**	14.7%	30.7	0.714	31.4%	0.0584
3	**CDRDF**	29.1%	14.1	0.390	78.7%	0.0216
4	**Total**	100.0%	16.9	0.431	46.5%	0.0500

Table 7 GHG reductions for 2024 using actual operational data

		A	B	C	D	E	F	G
	Period	Substitution rate ALCF	clinker production	heat consumption	heat from ALCF	GHG intensity base fuel	GHG intensity ALCF	GHG reductions
		%	**tonnes**	net GJ/tonne	net GJ	tonnes CO2/net GJ	tonnes CO2/net GJ	tonnes CO2e
1	**2024**	**20%**	*****	*****	*****	0.0621	0.0500	5,577

It should be noted finally that Heidelberg Materials uses multiple suppliers of C&D RDF and that the carbon content, biomass, and heat values used in the calculations were based on the C&D RDF that was supplied in 2024. One of those C&D RDF producers has ceased operations and will not supply C&D RDF to Heidelberg Materials in the future. The biomass content of the C&D RDF supplied by that producer contained lower biomass than the other producers so, going forward, Heidelberg Materials expects the biomass content of C&D RDF, and therefore of ALCF, to increase. Heidelberg Materials has used the 2024 figures to project GHG reductions from the project, but these projections should be considered conservative.

10.0 ENVIRONMENTAL, ECONOMIC, AND SOCIAL IMPACTS

10.1 OTHER ENVIRONMENTAL IMPACTS

The completed Project and advancement of technology have led to several immediate and potential future environmental benefits:

Immediate Environmental Benefits:

Diversion of Waste from Landfills: By using ALCF, the Project diverts waste from landfills, which significantly reduces methane emissions. Additionally, diverting waste from landfills conserves land, reduces soil and water pollution, and promotes a circular economy.

Reduced Need to Extract Fossil Fuels: The shift to ALCF reduces the need for fossil fuel extraction, which has several benefits: Lower Environmental Impact: Fossil fuel extraction often leads to habitat destruction, soil erosion, and water contamination. Reducing extraction helps preserve natural ecosystems.

Improved Human Health: Fossil fuel extraction and combustion release harmful pollutants that can cause respiratory and cardiovascular diseases. Reducing reliance on fossil fuels improves public health.

Potential Future Environmental Benefits:

Sustainable Land Use: The use of ALCF promotes sustainable land use practices. Biomass can be sourced from agricultural residues and other organic waste, reducing the need for landfills and promoting sustainable agriculture1.

Water Conservation: ALCF production and use typically require less water compared to fossil fuel extraction and processing. This helps conserve water resources and reduces the strain on local water supplies.

Overall, the Project's transition to ALCF not only reduces CO_2 emissions but also offers a wide range of environmental benefits, contributing to a more sustainable and healthier future.

10.2 PROJECTED ECONOMIC IMPACT

Heidelberg Materials benefits economically from the Project in three ways:

1) Avoided cost of natural gas. At full capacity (50% substitution rate) Heidelberg Materials will avoid purchasing between bet ween *****and ***** GJ of natural gas energy annually, depending on production. If natural gas prices are assumed to fluctuate between $*****/GJ and $*****/GJ in the near and medium term, then Heidelberg Materials will save between $***** and $***** annually from avoided purchase of natural gas.

2) Revenue from tipping fees. In the near and medium term, Heidelberg Materials will receive tipping fees for some, but not all, ALCF.

   a. RDF producer has agreed to deliver ***** annually of RDF with a tipping fee of $***** until 2028. It is not known if that agreement will be renewed at the same rate. Tipping fees from RDF = $*****

   b. Tire Recycler has agreed to supply between ***** of tire fibre annually with a tipping fee of $*****. Revenue from Tire Fibre = $*****

   c. C&D waste managers/ ALCF suppliers require payment between $***** and $***** C&DRDF delivered in the near and medium term, but efforts are ongoing to secure C&D RDF supply for lower cost. Assuming Heidelberg Materials will receive ***** C&DRDF annually at average cost $***** then revenue = $ *****

3) Sale of Environmental Performance Credits (EPC). The Project will reduce direct emissions by ~30 kt per year of CO_2 (refer to section 9.3). Assuming that an Industrial CO2 pricing system remains in place in Alberta, this will either allow Heidelberg Materials to generate EPC or avoid an obligation. The value of those reduction will depend on market conditions at the time the reductions are made.

Waste Managers are also expected to benefit economically from avoided transportation and landfill fees when waste is transformed into ALCF. The extent of those savings is not known to Heidelberg Materials since this represents business confidential information to the suppliers.

10.3 RESULTED INNOVATION CAPACITY

The Project has boosted innovation capacity in the province through various avenues:

Training of Highly Skilled Personnel: The introduction of ALCF (Alternative Low-Carbon Fuels) to the kiln at the cement plant necessitated the training of personnel in innovative control strategies and ALCF management processes. This has enhanced the skill set of the workforce, making them more adept at handling advanced technologies and processes.

Knowledge Development: The Project has fostered the development of new knowledge in the field of ALCF management and integration. This includes the creation of innovative control strategies for the kiln and the development of processes to manage ALCF effectively.

Startup Companies: The Project has also spurred the growth of startup companies focused on ALCF production and integration. These startups are at the forefront of developing new equipment and methods, driving innovation in the waste management sector.

Supplier Level Innovations: At the supplier level, waste managers have integrated ALCF production equipment and methods into their operations. This integration has required innovative approaches to waste management, further enhancing the province's overall innovation capacity.

Overall, the Project has created a robust ecosystem of innovation, involving skilled personnel, academic institutions, research organizations, and startups, all contributing to the province's enhanced capacity for innovation.

10.4 SOCIAL IMPACT AND EDI OUTCOMES

The Project has a positive impact on various communities, particularly local and underserved groups. By supporting jobs and fostering innovation in the waste management sector, the Project has created employment opportunities for individuals who often face barriers to finding work elsewhere. This includes people from marginalized backgrounds, those with limited access to education, and individuals with disabilities.

11.0 SCIENTIFIC ACHIEVEMENTS

Heidelberg Materials did not obtain patents, publish books or journal articles, make any external conference presentations, or develop any student theses based on work conducted during the Project.

12.0 POST-PROJECT STEPS

12.1 NEXT STEPS AND FOLLOW-UP PROJECTS

The next steps for Heidelberg Materials are:

1) Refine and de-bottleneck ALCF and kiln process systems to maximize substitution rate at Edmonton plant.

2) Develop and maintain a robust and sustainable supply chain for ALCF.

3) Develop ALCF Projects at Heidelberg Materials cement plants in North America applying lessons learned from the Edmonton Project.

12.2 PARTNERSHIPS

Heidelberg Materials does not intend to develop partnerships with technology integrators, adopters, or similar with respect to this Project.

13.0 OVERALL CONCLUSIONS

The Lehigh Edmonton Alternative Low Carbon Fuel Project, implemented by Heidelberg Materials Canada Limited, achieved significant outcomes in terms of greenhouse gas (GHG) emissions reductions and environmental benefits. The project involved the installation of systems and infrastructure to receive, store, and feed waste-based alternative low carbon fuels (ALCF) to the cement kiln system at the Edmonton plant.

Project Outcomes:

Successful Implementation: The project successfully installed and commissioned the necessary infrastructure to handle ALCF, achieving an 82% system uptime during the operational phase.

Operational Performance: The project maintained steady-state kiln operation while injecting ALCF, achieving a 30% replacement rate of fossil fuels with ALCF for 30 out of 175 operating days.

Cost Savings: The project demonstrated cost savings of $***** million during the performance measurement period, excluding future revenue from avoided emissions credits.

Environmental Compliance: Emissions testing results while using ALCF were compliant with permit targets and equivalent to historical performance without ALCF.

GHG Emissions Reductions:
Direct GHG Emissions Reductions:
Annual: 25.6 ktonnes (average 2025-2030 – this will vary with production)
Cumulative by 2030: 153.5 ktonnes (dependent on production)
Cumulative by 2050: 728.5 ktonnes (dependent on production)

The project not only reduced GHG emissions by replacing fossil fuels with ALCF but also contributed to environmental sustainability by diverting waste from landfills, reducing methane emissions, and lowering the need for fossil fuel extraction. These outcomes highlight the project's success in advancing low-carbon technologies and promoting sustainable practices in the cement industry.

14.0 COMMERCIALIZATION AND TECHNOLOGY TRANSFER PLAN

14.1 PROJECT COMMERCIALIZATION ADVANCEMENTS

Heidelberg Materials' commercialization strategy is primarily concentrated on achieving it's ALCF targets in Edmonton. Heidelberg Materials is furthermore concentrated on developing ALCF the technology at the 14 cement plants that Heidelberg Cement owns and operates in North America which do not yet have ALCF technology installed. In particular, similar Projects are currently being developed at the Picton facility in Ontario and the Mitchell facility in Indiana, as well as an expansion of the ALCF facility already installed at the Delta facility in British Columbia. In all cases, lessons learned from the Edmonton Project are being applied, and technical staff are being directly engaged. The Edmonton project serves as a lighthouse project that showcases the feasibility and benefits of using ALCF in cement manufacturing and provides direct experience to Project managers and operational staff.

The operational phase of the Project confirmed that ALCF can be used successfully to make portland cement while maintaining production, quality, and environmental performance targets. The project has facilitated the transfer of knowledge to North American operations of Heidelberg Materials. This includes sharing best practices, operational insights, and lessons learned from the Edmonton project.

In addition, Heidelberg Materials is actively commercializing low carbon cement and concrete products made using ALCF, both through direct engagement with customers and development of updated Environmental Product Declarations.

With respect to gaps in commercialization, ensuring a stable and consistent supply of ALCF remains a focus. This includes managing the variability in quality and availability of feedstock.

Update on Commercialization success metrics from Contribution Agreement:

Table 8 Commercialization success metrics update

Success Metric	Commercialization targets from CA	Commercialization targets after project completion	Explanation
System Uptime (reliability)	> 70% uptime of ALCF system uptime while kiln is operating.	> 70% uptime of ALCF system uptime while kiln is operating.	System uptime 82% already achieved during operational phase
ALCF Replacement Rates	Steady state operation at 50% replacement achieved.	Steady state operation at 50% replacement achieved.	System refinements to allow increased substitution rates scheduled for April 2025 shutdown.
Environmental Compliance	Exhaust gas quality while using ALCF 100% compliant with permit	Exhaust gas quality while using ALCF 100% compliant with permit	100% compliance with permit already achieved during operational phase.
Economics	Demonstrate cost savings at Edmonton plant while using ALCF at 50% replacement compared to business as usual.	Demonstrate cost savings at Edmonton plant while using ALCF at 50% replacement compared to business as usual.	Cost savings already demonstrated during operational phase.

14.1.1 PROJECT TECHNOLOGY ADVANCEMENTS

The technology advanced from engineering and design to construction and commissioning over the course of the Project. This advancement allows Heidelberg Materials to realize cost and GHG emissions reductions at commercial scale in Edmonton.

14.1.2 PROJECT TRL ADVANCEMENTS

The technology Readiness level advanced from TRL 8 at the beginning of the Project to TRL 9 upon completion.

14.2 TECHNOLOGY PROVISION AND THIRD-PARTY VENDORS

Heidelberg Materials' intent was to commercialize the use of Alternative Low Carbon Fuels (ALCF) to make portland cement at Edmonton and within the Heidelberg North American organization and to commercialize low carbon products made using ALCF. The intent was not to develop technology that would be commercialized directly to third parties.

Third party vendors required to commercialize the technology include equipment suppliers that produce cranes, tubular conveyers, and dosing equipment. Proposals for the main process equipment supply were received from four vendors for this Project. Schenck (now known as Coperion) was chosen as the successful bidder, but the other bidders could also have provided the technology.

14.3 COMPETITIVE SCAN

It is well understood that Heidelberg Materials competitors are developing similar ALCF technology at cement plants around the world. Lafarge Canada for instance also completed an ALCF project with similar scope at their facility in Exshaw, Alberta in 2024.

14.4 MARKET AND END-USERS

Heidelberg Materials' intent was to commercialize the use of Alternative Low Carbon Fuels (ALCF) to make portland cement within the Heidelberg North American organization and to commercialize low carbon products made using ALCF. The intent was not to develop technology that would be commercialized directly to third parties.

14.5 MARKETING

Heidelberg Materials' intent was to commercialize the use of Alternative Low Carbon Fuels (ALCF) to make portland cement within the Heidelberg North American organization and to commercialize low carbon products made using ALCF. The intent was not to develop technology that would be marketed externally.

Heidelberg is fully engaged in promoting and marketing low carbon cement and concrete products. In addition to direct engagement with customers, Heidelberg Materials uses Environmental Product Declarations (EPD) that are developed using internationally recognized standards to demonstrate performance. Improvements that are realized due to the use of ALCF are incorporated directly into the EPD.

14.6 DISTRIBUTION

Heidelberg Materials' intent is to commercialize the use of Alternative Low Carbon Fuels (ALCF) to make portland cement in Edmonton and within the Heidelberg North American organization and to commercialize low carbon products made using ALCF. The intent was not to develop technology that would be distributed externally.

Implementation of the Project was coordinated through Heidelberg Materials' North American Cement Competency Centre. The project managers and technical personnel involved in the Edmonton Project are directly involved with developing similar projects at other facilities in North America.

14.7 TECHNOLOGY PROTECTION

The Project did not involve development of proprietary technology.

14.8 COST OF COMMERCIALIZATION

Heidelberg Materials' intent is to commercialize the use of Alternative Low Carbon Fuels (ALCF) to make portland cement in Edmonton and within the Heidelberg North American organization and to commercialize low carbon products made using ALCF. The intent is not to commercialize the technology externally.

14.9 SHORT-TERM ACTIONS

The short-term plan is to achieve 50% substitution rates at the Edmonton plant and to develop similar projects at Picton, Ontario and Mitchell, Indiana. These projects are expected to be under construction within two years of Project implementation.

14.10 LONG-TERM COMMERCIALIZATION

The long-term plan is to maintain 50% substitution rates at the Edmonton plant and to develop similar projects beyond the Projects currently under development at Picton, Ontario and Mitchell, Indiana. These projects are expected to be under construction within two years of Project implementation.

15.0 COMMUNICATIONS PLAN

15.1 KNOWLEDGE SHARING DURING PROJECT

Project knowledge and objectives were communicated with customers, ALCF suppliers during development of the Project.

Additionally, Project knowledge and objectives were shared with various Government agencies for the purpose of soliciting support for the large-scale Carbon Capture and Storage project that is being developed for the Edmonton cement plant. The ALCF project is critically important to the CCS project because sequestering emissions from combustion of biomass results in carbon dioxide removals, over and above reductions.

15.2 KNOWLEDGE SHARING POST PROJECT

Heidelberg Materials does not intend to communicate detailed information about the Project, Project findings, or results with third parties. Heidelberg will communicate high level Project information to customers when it is beneficial to do so for the purpose of promoting low carbon cement and concrete products to customers.

16.0 LITERATURE REVIEWED.

Not Applicable

17.0 DEFINITIONS

Definitions and acronyms are described directly in the body of this report where applicable/necessary.