Carbon Upcycling Technologies
Emissions Reduction Alberta Non-Confidential Final Report

ERA Project ID:	E0160696
Title of project:	Carbon Nanoplatelet Production from Exhaust CO2 Emissions
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Completion date of the project:	September 22, 2021
Total ERA funds received:	$1,500,000
Final outcomes report submission date:	October 4, 2021

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Executive Summary

Carbon Upcycling Technologies (CUT) planned to scale-up the production capacity of its CO2-Enhanced additive manufacturing facility at the Alberta Carbon Conversion Technology Center (ACCTC) in Calgary, Alberta. This scale-up ultimately produced a 20 tonne per day (tpd) capacity and was an extension of a previous project started in January 2019 to commercialize a 1 tonne per day capacity facility. The modular, 20 tpd facility was constructed for participation in the NRG COSIA Carbon XPRIZE and was commissioned in August 2020 and fully operational in March 2021. CUT's goal is to continue the operation of the facility for commercial and research purposes until June 2022. The project will continue to include the Phase I ACCTC Demonstration. The 20 tpd of production capacity was achieved by a stepwise scaleup approach, starting with a reactor processing 2 grams, 10 kg (Delta), 3 tonnes (Zeta), and then 20 tpd (Eta).

Throughout the program, CUT has completed 6 major milestones: 1) Project Definition & Design, 2) Commissioning of Enhanced Fly Ash Units, 3) Commissioning of Enhanced Fly Ash Units, 4) Quality Control and Optimization, 5) Operations and Market Rollout, and 6) Operations, Further Commercial Testing, Efficiency Improvements.

CUT's patented technology can be described as a pressurized catalytic ball mill that combines inorganic feedstocks and CO2 that results in the permanent sequestration of CO2 onto the feedstock. The end product is a CO2-Enhanced additive that can be used in concrete and other applications to lower the carbon footprint of the end product.

In concrete applications, CO2-Enhanced fly ash is used and it has been validated by a third party to be regulatory compliant for use in concrete in North America. CUT CO2-Enhanced fly ash provides strength and durability improvements in comparison to a standard concrete mix using untreated fly ash. The results demonstrate that with both the permanently captured CO2 in the CUT CO2-Enhanced fly ash and the double-digit cement reductions, the optimized mix designs are able to reduce the CO2 footprint by >15% per cubic meter of concrete. These results have allowed CUT to make significant commercial traction, resulting in strategic MOUs with LafargeHolcim and CEMEX.

The 20 tpd facility in Calgary treats fly ash for both BURNCO and Lafarge; however, beyond fly ash, CUT's technology has shown promising results through the smaller Delta reactors with other pozzolanic materials. By exploring alternative materials, CUT's technology becomes more and more relevant to other geographical markets.

CUT is introducing a novel technology into the risk-averse cement and concrete industry. With continued support from Emissions Reduction Alberta, CUT has been able to successfully scale up its carbon utilization technology in Alberta, but not without great learnings generated from the intricacies of sustainable policy and procurement, engineering at scale, and big industry's grueling and comprehensive technical due diligence. Yet, through it all CUT remains persistent in reaching its goal of being the most impactful carbon utilization company of the 2020s.

Project Description

Introduction

Carbon Upcycling Technologies (CUT) had proposed a project to scale its production capabilities to produce 8 tonnes per day of CO2-embedded cementitious materials to enable the construction of low carbon construction materials in the Alberta market. This scale-up ultimately produced a 20 tonne per day (tpd) capacity and was an extension of a previous project started in January 2019 to commercialize a 1 tonne per day capacity facility. The commercial-scale pilot plant was to leverage CUT's patented MACE (Mechanically Assisted Chemical Exfoliation) technology which captures CO2 emissions directly into feedstock such as coal ash, graphite, petroleum coke, and other inorganic materials. CUT intended to commercialize the Enhanced Fly Ash additive (EFA-100) for use as an additive in concrete to reduce greenhouse gas emissions (GHGs) and reduce cement consumption in the construction industry. The proposed project was to serve local ready-mix and precast companies in Alberta including BURNCO, LafargeHolcim, and CRH. CUT will further develop the technology to TRL 9, and provide sufficient quantities to conduct regulatory requirement testing. The project was also intended to demonstrate the integration of CUT's process with a point source emission, like but not limited to the flue gas from a natural gas power plant.

Technology

CUT was founded to validate, scale, and commercialize a process to permanently sequester gaseous CO2 emissions into cheap solid feedstock such as graphite and fly ash, thereby upcycling them into producing a range of CO2-negative, and value-added nanoparticles. After an extensive literature review of various chemical processes that convert CO2 into solid carbonates, biofuels, organic compounds, and others, CUT's executive team determined that an effective pathway to CO2 utilization involved a process that facilitates the adsorption of CO2 on exfoliated solid feedstock. In Summer 2014, CUT devised a reactor to facilitate the capture of CO2 into the chemical and physical structure of a solid adsorbent. The intent was to physically and chemically adsorb CO2 molecules onto a solid substrate in a manner that would only release the adsorbed CO2 at elevated temperatures in excess of 100 degrees Celsius.

CUT's initial intent was to use commercial technology to promote the adsorption of CO2 by exfoliating the solid carbon feedstock. It was hypothesized that the exfoliation of the solid material would create porosity and chemically active sites that could bond to CO2 or, at a minimum, stably entrain the gas through physical adsorption. Through an extensive literature review that was carried out through Summer 2014, CUT determined that conventional methods of chemical exfoliation were too energy-intensive and that a new, low-energy method needed to be devised for economically feasible adsorption of CO2.

Accordingly, CUT proceeded to develop a low-energy exfoliation process that required the minimal intervention of catalysts and operated at ambient temperature and low pressure. CUT has scaled its ability to capture CO2 emissions from point sources by over 10,000,000 times and has technically validated the performance of its end products in over 10 different industrial markets. CUT has identified the significant potential for GHG reductions and economic growth in Alberta through production adoption in the cement industry. Oldcastle

Infrastructures, one of the largest precast companies in North America, possesses over 90 facilities in the US and has already begun testing various CUT admixtures with their precast blends.

EFA-100 is composed of CO_2 that is gathered from a point source of emissions, such as a natural gas plant, and fly ash - a byproduct of burning coal. The material can then be added to cement mixtures to make concrete. Therefore, EFA-100 reduces carbon emissions in two ways: through sequestered CO_2 into the fly ash and through less cement usage. Typically, >80% of carbon emissions associated with a cubic meter of concrete is a result of the cement production process.

EFA-100 will advance in technological development during this proposed project as the scaled-up demonstration site will allow for participation in larger infrastructure projects. Currently, CUT has a 1 tpd facility which has been labeled “lab-scale” due to the high volume of EFA-100 that is required to enter the construction industry.

CUT has commissioned 13 reactors to date which range in capacity from 1 gram to 1 tonne per day production scale. Through this phased scaleup CUT increased its production capacity of EFA by over 10,000,000 times relative to its capacity at project commencement.

CUT’s platform technology is the production of exfoliated nanoparticles from abundantly available, low-cost solids and sequestered CO_2 emissions. The commercial use of CUT’s CO_2-derived products in place of highly CO_2-intensive materials that are currently used in these industries will facilitate a more circular economy and lower GHG emissions both directly and indirectly. The technology would be advanced through market uptake of EFA-100 and through commercial validation of the product.

It is important to note that although CUT’s initial foray into the construction industry utilizes legacy coal ash as its adsorbent, the technology has already shown the ability to increase the surface area and reactivity of a range of other pozzolanic materials. CUT’s long-term goal is to devise a product that uses other pozzolans that can adsorb CO_2 and produce a high-performance alternative to partially or fully replace the use of portland cement in the construction industry- thereby transforming the CO_2-intensive construction industry into a carbon sink.

Project Objectives and Work Scope Overview

The work scope includes the following particular tasks that will need to be completed for the successful execution of the proposed project.

Milestone 1: Project Definition & Design:

- Finalize design and engineering of Zeta and Eta reactor units from November 22, 2019 - April 10, 2020.
- Completed piping and instrumentation diagrams will allow for the procurement of equipment and fabrication of the Eta pressure vessel and skid.
- Completed Bill of Materials for the drive train, material handling, CO_2 systems

- Delivery to ERA of a draft Commercialization and Technology Transfer Plan, and a corporate staffing plan.

Milestone 2: Procurement, Fabrication & Construction: CUT will engage with local and international suppliers to procure equipment for the Zeta and Eta units. At the Alberta Carbon Conversion Technology Centre, CUT will use local contractors and site staff to finish construction on the Zeta reactor and commence construction of the Eta reactor. This milestone will commence from November 22, 2019, and be completed by July 15, 2020.

Milestone 3: Commissioning of Enhanced Fly Ash Units:

- Assemble and commission the EFA-100 facility for demonstration at a commercial scale. This will be completed for both units; from March 1, 2020, to March 20, 2020 for the Zeta reactor and from June 1, 2020, to August 10, 2020, for the Eta reactor.
- This will include working with controls specialists to ensure proper feedback loops, automation, safety valves, and protocol have been installed, including:
    - Integrated Drivetrain runs,
    - Load sharing VFD system check,
    - Coupled and uncoupled runs with the vessel load
- Concerns around smooth operation will be addressed through systematic trials prior to the full commissioning of the facility.

Milestone 4: Quality Control and Optimization:

- Implementation of a QC Protocol with the product from the EFA-100 facility to ensure the process and carbon nanoparticle quality from the system can be assessed reliably at a commercial scale. Specifically:
    - Determine optimal conditions to reproduce low, and high-processing results achieved at BURNCO (20+ and 36%+ compressive strength at 28 days, respectively),
    - Repeat testing cycled with Zeta and Eta reactors in high processing condition at least 5 times or, produce a minimum of 20 tonnes of the product of high processing performance.
- The quality control and optimization will start on April 15, 2020, during commissioning and will be completed by August 30, 2020. The QC protocol developed, iterated, and refined through the first three prototypes will be implemented as a template during the initial commissioning of the EFA-100 facility and modified thereafter, as deemed necessary. Typically, this would include the use of technical personnel and equipment such as BET surface area, SEM, FTIR, and TGA-MS.
- The operation and design of the EFA-100 reactor will be modified and refined to ensure optimal performance

Milestone 5: Operations and Market Rollout: Post-optimization of the EFA-100 facility, CUT will begin to roll out its product into the concrete industries from April 15, 2020, to January 1, 2021. By this stage of the project, CUT will be able to offer industrial amounts of product to clients in the target markets through full-time operations of undisrupted production cycles to produce 8 tpd of EFA. Safety testing will result in Safe

Work Procedures. The rollout phase would include the following activities (generally referred to as system testing to ensure the product meets all criteria within the supply chain-

1. Product testing and validation with a concrete partner (BURNCO and Lafarge)- at least 5 rounds,
2. Confirmed no issues exist with product handling and on-site storage,
3. Product deployment in field trials, including on-field measurements for air entrainment, workability, and product consistency - at least 10 deployments with 2 or more mix designs,
4. Batch-to-batch QC variability (less than 15% change in compressive strength values for 10 production batches.
5. Field use of more than 100 tonnes of EFA,
6. Verified testing data for Supplementary Cementitious Materials (SCM) compliance as per CSA 3000.1, including validated ASR (Alkali Sulfate Resistance) and Sulfate Resistance testing.

Milestone 6: Operations, Further Commercial Testing, Efficiency Improvements: Post-optimization of the EFA-100 facility, CUT will begin to roll out its product into the concrete industries from January 1, 2021, to June 30, 2022. By this stage of the project, CUT will be able to offer industrial amounts of products to clients in the target markets. CUT will engage its market partners and consultants within Alberta as well as in other areas of the world to execute an aggressive market outreach plan. Optimization and efficiency improvements will be made based on the analysis made in milestone 4, the systems testing in milestone 5, and lessons learned from full-time operations. CUT will issue a final report on its progress at completion of the project in late June 2022, along with its success relative to its planned tasks, milestones, and its defined success metrics.

LafargeHolcim will be re-engaged as a partner to further the commercial-scale testing and demonstrations of EFA in concrete. Their support will be confirmed in the form of a letter denoting the monetary value of their in-kind work which will include both field and lab trials.

Project Outcomes and Learnings

Technology Development, Installation, and Commissioning Description
CUT was at technology readiness level (TRL) 6 at the beginning of the project and at project completion is at TRL 8.

Between November 2019 and July 2020, CUT finalized the design and engineering of Zeta and Eta reactor units, completed piping and instrumentation diagrams that allowed for the procurement of equipment and fabrication of the Zeta and Eta pressure vessel and skid. CUT also completed the Bill of Materials for the drive train, material handling, and CO_2 systems for both units.

CUT engaged with local and international suppliers to procure equipment for the Zeta and Eta units. At the Alberta Carbon Conversion Technology Centre, CUT used local contractors and site staff to finish construction on the Zeta reactor and commence construction of the Eta reactor.

CUT partially commissioned and ran the 1 tonne per day reactor, Zeta, for the first time at ACCTC on March 18th, 2020 with fly ash and CO2. However, the ACCTC was shut down due to restrictions during the COVID crisis on March 20th, 2020. The ACCTC was reopened on April 27th with limited capacity and the CUT team worked at the company's Bearspaw facility to construct the skid for the Eta reactor. Despite delays on small parts for the reactor, the vessel for Eta was still on track.

After the construction of the Zeta and Eta reactors, CUT successfully commissioned both reactors for demonstration at a commercial scale. The commissioning included working with controls specialists to ensure proper feedback loops, automation, safety valves, and protocol have been installed, including:

- Integrated Drivetrain runs,
- Load sharing VFD system check,
- Coupled and uncoupled runs with the vessel load

Concerns around smooth operation have been addressed through systematic trials. CUT put in place operational procedures of the units so that staff runs the reactors. Since commissioning the Eta reactor, CUT has implemented QC Protocols for all of the reactors. There have been no safety incidents due to the operations of the reactors and no unexpected maintenance to date. However, after commissioning the Eta and Zeta reactor, a couple of significant engineering issues were found that are associated with the material handling element of our operation. These errors required fixes before the reactors could run continuously and the errors have now been addressed.

As part of technology development, CUT started trials with other pozzolans, which show promise as commercially viable products.

Commercialization Advancements

CUT has made significant commercial traction over the last two years that have resulted in multiple strategic MOUs that have included comprehensive material testing programs, commercial deployment, and exploration of future strategic investment and facility development. MOUs and commercial partnerships are listed and detailed below:

LafargeHolcim - Began with a 2-tonne material evaluation in the Zeta reactor; in July 2021 Lafarge began the commercial process of fly ash, delivering 40 tonnes per week to be treated in Eta and the processed material was delivered for use in Calgary and Edmonton. The MOU is set to conclude in December 2021 with a discussion of future strategic investment and facility development. The LafargeHolcim Western Canada team has ambitious targets for CCUS and low carbon concrete, and CUT would work with this business unit before looking at international development opportunities.

CEMEX - Engagement began in February 2020, and since then, we have completed a comprehensive material evaluation program that analyzed materials from around the world. Results were promising and now we are in discussion for future developments that will be integrated at a US cement plant.

BURNCO - BURNCO started by delivering material to be treated in Zeta in 2019, and since the commissioning of Eta, BURNCO has increased the delivery quantity to 40 tonnes per week for treatment and deployment in the greater Calgary area. Through projects with

BURNCO, CUT was able to demonstrate an ability to reduce cement content by >10% in concrete mixes.
Virgin Hyperloop - CUT has supplied material to the material evaluation team that is exploring the use of the concrete additive in its infrastructure projects.

In addition to the commercial partnerships, CUT has been committed to educating and engaging with engineering firms, architects, and designers. O2 Design has specified CUT CO2-Enhanced fly ash in the exterior concrete development at the Telus Spark in Calgary, AB. In addition to that marque project, CUT CO2-Enhanced fly ash is being incorporated in the foundational concrete for sustainable home development in Alberta; the project was supported by a Smart Sustainable Resilient Infrastructure Associate (SSRIA) grant.

Analysis of Results
CUT's technology has been tested on various sources of fly ash, including two Alberta sources in Eta, two Alberta sources in Zeta, and 5+ sources from local and global in Delta. Beyond fly ash, CUT's technology has shown promising results through the Delta reactors with natural pozzolanic materials. By exploring alternative materials, CUT's technology becomes more and more relevant to the global market, which will help unlock new feedstocks that will build more sustainable and resilient infrastructure.

Comprehensive third-party lab testing and verification have proven that CUT CO2-Enhanced fly ash is compliant with CSA standards for fly ash. The CUT CO2-Enhanced fly ash results show strength improvements of >30% while still meeting the physical characteristics and properties of untreated fly ash.

CUT's local commercial concrete partner, BURNCO, has deployed over 600 tonnes of fly ash into commercial projects since April 2021. BURNCO's optimized mix design has a 10% cement reduction, which is the largest cement reduction proven at a continuous commercial scale across the entire concrete industry. The optimized mix design has been used in sidewalks, foundations, curbs, and gutters across Southern Alberta.

In collaboration with XPrize and the University of Calgary completed a comprehensive Life Cycle Analysis for the use of CUT CO2-Enhanced fly ash in concrete. The results demonstrated that with both the permanently captured CO2 in the CUT CO2-Enhanced fly ash and the double-digit cement reductions, the optimized mix designs are able to reduce the CO2 footprint by >10% per cubic meter of concrete. With further mix design optimization, the CO2 footprint will be reduced by upwards of 20% per cubic meter.

Discussion of Challenges, Delays, or Obstacles
In June 2020, due to COVID-19 delays and in-kind support reductions, CUT requested the reduction of scope to include only what was needed to progress the Zeta and Eta units from design to operational status while including the operating costs of smaller reactor units primarily used for testing purposes. This included removing funding CUT had allocated to activities such as spray gun application for the AlphaCarbon corrosion coating product line. This did not affect major deliverables or timeline but the budget was reduced.

Important Lessons Learned

Over the last two years across North America, governments and municipalities have begun discussing and incorporating mandates that require the use of low-embodied carbon materials. The Canadian Federal government has set a target of 40% lower CO_2 for the concrete industry. As the Federal government's procurement initiatives and mandates gain more traction in order to meet the ambitious climate targets, these initiatives and mandates will have a trickle-down effect on the rest of the market, which will generate market-driven demand for concrete producers to accelerate the investment and incorporation of CUT technology into their supply chains. CUT has learned patience through gaining more knowledge of policy development and integration, but CUT has remained perseverant in continuing to conduct testing to validate the CUT CO_2-Enhanced fly ash in commercial projects.

Regulatory standards, including CSA, are becoming more flexible to allow alternative supplementary cementitious materials (SCMs) into the market. SCMs, like fly ash, have been used for the last 30 years to lower the carbon footprint of concrete, but with supplies running low in many locations across North America, we have learned that companies are now shipping in fly ash from overseas. With this understanding, CUT recognized the opportunity to explore alternative SCMs that could be treated through the technology. There is also promising initial data that CUT has collected that shows that even low-quality alternative SCMS could be improved to meet the current SCM specifications to then be used in concrete; therefore, creating a local, high-performance, and more sustainable SCM, instead of importing SCMs from overseas.

Given the high-volume, low-margin dynamic of the concrete industry, material providers need to produce a significant amount of products to have an economic impact on the market. CUT has now learned that the requisite volume for a commercial facility will be 200 tonnes per day or greater.

Greenhouse Gas Reductions and Benefits

Supporting data were not available to ERA at the time of report finalization and project audit. A complete set of supporting data for actual and forecasted emissions reductions will be provided to ERA in post-project annual reports. These projected estimates of GHG reductions are based on the use of renewable power sources. Actual emissions reductions will be based on site-specific conditions.

Eta reactor facilitates meaningful reductions of carbon emissions through cement substitutions in field deployments. To date, the GHG reductions associated with the project include roughly 50 tonnes of CO_2 directly sequestered and over 1000 tonnes of CO_2-Enhanced fly ash has been used in field projects.

The project reduces emissions in two ways: firstly, through the direct sequestration of carbon emissions from the flue stack of a natural gas power plant (namely, the Shepard Energy Centre) and, secondly, through the displacement of cement in concrete mix designs with a high performance supplementary cementitious material.

Importantly, the project enables the deployment of commercial installations of CUT technology into the field, allowing for double-digit emissions reduction in concrete.CUT continues discussions with Lafarge, BURNCO, CEMEX, and a host of ready-mix and concrete companies in Canada and internationally to enable the deployment of its reactors to reduce clinker content in cement and cement content in concrete by between 10 and 30%. This is best evidenced by Carbon Upcycling's MOUs with LafargeHolcim and CEMEX- 3 of the 10 largest cement companies in the world, establishing CUT as the only company with that level of traction with the major vertically integrated Tier 1 cement companies.

With Alberta's dependence on local cement production, as well as local pozzolan availability, there is a large potential for reducing GHG in the province. Between now and 2025, it is anticipated that CUT will deploy at least two commercial facilities totaling 400 tonnes per day of production. At this scale, CUT will reduce GHG by more than 55,000 tonnes per year in Alberta. It is estimated that CUT's technology could reduce CO_2 emissions by over 500,000 tonnes each year if 20% of the province's cement production was matched with Carbon Upcycling's concrete additive.

Economic and Environmental Impacts

CUT has utilized two primary feedstocks in its process: CO_2 gas and carbonaceous/mineral solids. Fly ash as a feedstock can be procured at discounted costs due to the disposal and inventory expenditures the holders pay currently. For CO_2 procurement, CUT is attached to the Enmax Shepard Energy Centre which neighbors the ACCTC and uses a slipstream of concentrated CO_2 sourced from the plant's flue stack. CUT has assumed a cost of USD 100 per tonne of gaseous CO_2 in its economic analysis.

For the 20 tpd facility, it is a demonstration and will be a template for licensing and joint ventures across the world where fly ash can be upcycled and used in place of cement. As such, the demonstration is not a commercial-scale facility but will show the maturity of technology ready for global deployment.

Another economic benefit of this demonstration site is the creation of jobs in Alberta. The below tables provide a breakdown of the jobs created in this scale-up:

Developing Talent – HSP generation during the course of the project

Employment Type	Existing HSP	New Hires	Person-Years of Employment
Academic HSP*	2	2	4
Industry HSP**	1	4	10
Other HSP	0	0	0
Construction and Trades	0	2	3
Other Non-HSP	0	3	1.5

*This includes Faculty, Post-Doctoral Fellows, Graduate Students, Research Associates, Undergraduates, etc.

**This includes Professional, Management, Technologists, as well as Operations and Maintenance Personnel, etc.

Job Creation – Estimated HSP generation for commercial deployment of the technology

HSP Type	Existing HSP	New Hires	Person-Years of Employment
Academic HSP*	4	10	30
Industry HSP**	5	10	25

Other HSP	0	0	0
Construction and Trades	2	30	66
Other Non-HSP	3	5	26

*This includes Faculty, Post-Doctoral Fellows, Graduate Students, Research Associates, Undergraduates, etc.
**This includes Professional, Management, Technologists, as well as Operations and Maintenance Personnel, etc.

The operational demonstration project has the potential of producing multiple social benefits within Canada. Firstly, the project revolves around the space of advanced materials and the development of emerging technology space. Projects in this space have historically produced a job multiplier of 10:1 relative to conventional primary resource projects that average 3:1 indirect jobs per direct job produced. Additionally, the commercial scale of the project provides a real-life example of industrial utilization of CO_2 that can improve societal efficiency and promote workforce allocation in the clean technology and advanced material (i.e. nanoparticle) industries. Through direct jobs within CUT and pertinent research at associated Universities and research institutes, the project facilitated further opportunities for post-secondary education in the area of GHG abatement and advanced materials. The demonstration project also assisted in shifting the public narrative on CO_2 towards upcycling and market-driven industrial use, thereby offering a practical example of moderate policies in contrast to the often-polarized debate on the perceived choice of societal prosperity and environmental stewardship.

Overall Conclusions

CUT is introducing a novel technology into the risk-averse cement and concrete industry, but with continued support from Emissions Reduction Alberta, CUT has been able to successfully scale up its carbon utilization technology in Alberta, but not without great learnings generated from the intricacies of sustainable policy and procurement, engineering at scale, and big industry's technical due diligence. Yet, through it all CUT remains persistent in reaching its goal of being the most impactful carbon utilization company of the 2020s.

Scientific Achievements

Regulatory Compliance
Tetra Tech Canada Inc. (Tetra Tech) has been testing the fly ash samples since 2020. This summary report is compiled to provide a comprehensive analysis of the properties of the fly ash sourced from Battle River and fly ash that underwent proprietary treatment developed by CUT. The testing results indicate that the low and high treatment of the Battle River ash results in altered physical characteristics of the ash and impacts the properties of concrete. The findings are summarized as follows.

- The upcycling process does not alter the chemistry of the ash.
- The upcycling process densifies the ash; specific gravity is increased and the ash is finer. These findings were confirmed by SEM analysis; treated ash particles were predominantly crushed and only small fly ash spheres remained intact. In general, SCM that is finer is expected to be more reactive.
- The strength activity is increased at 7 days and 28 days when compared with the untreated Battle River ash. Based on the accelerated testing for ASR with a 20% fly ash replacement level, the untreated Battle River ash did not mitigate against ASR.

Low level and high-level treatment ash was effective in ASR mitigation and exhibited expansions that were three times smaller when compared with untreated ash.
- Low treatment and high treatment Battle River ash are effective in mitigation against sulphate attack at 15%, 20%, and 30% replacement levels.

Patents
CUT has patented a process to activate a range of carbonaceous and mineral feedstocks to chemically and physically adsorb. The two subsequent patents were focused on the activation of supplementary cementitious materials for use in construction. Additional patents in this category will be filed later this year.

Next Steps

Technology and Process Innovation
CUT has had interest from clients to have a continuous processing technology. Currently, preliminary engineering research is being done to evaluate this process improvement for future scale-up. Additionally, CUT is identifying and testing alternative SCMs that could be treated through the technology, which unlocks greater market expansion opportunities. Interest from clients has also encouraged CUT to evaluate the range and limitations of the CO_2 source used. Currently, research is underway to evaluate different flue gas and CO_2 stream concentrations to establish lower bound characteristics for gas sources.

Long-term Commercialization Plan
CUT is working through commercial facility development opportunities with several commercial partners for both expansion within Western Canada and the United States. Opportunities are for the traditional SCMs and alternative SCMs. To meet the scale needs of clients, a larger scale-up will be required; the proposed scale is to build a facility that has a 200 tonne per day throughput capacity.

Regulatory testing that was completed during this project has proven that CUT CO_2-Enhanced fly ash and other alternative SCMs have not just met durability requirements, but actually exceed current standards. This unlocks commercial opportunities in geographic regions that at the beginning of the project were not being considered.

Next 2 Years Commercialization Actions
CUT will be designing, engineering, and commissioning the next facility that will be a 10x scale-up compared to Eta. In order to successfully execute on this level of scale-up, CUT will be selecting a strategically aligned EPC firm to assist with the engineering of the next iteration and potentially further scaleup and technology developments. Current market opportunities will allow for facility developments with clients outside of Alberta.

Partnership Development
CUT will continue to fulfill the obligations in the current MOUs with LafargeHolcim and CEMEX to further develop technical and performance confidence with these key clients, which make up 3 of the world's top 10 cement and concrete companies. We continue to engage with other cement and concrete companies both in Canada and around the world to build market-specific cases for further development and deployment of CUT technology.

Communications Plan

Over the duration of the project, CUT issued multiple press releases that captured the attention of major media channels and resulted in BNN interviews, PBS NOVA feature, and multiple local news interviews and features.

In addition, CUT published several case studies that showcased a variety of commercial projects that utilize CUT CO2-Enhanced fly ash in concrete and achieved double-digit cement reductions.

CUT also hosted facility tours for potential clients, key decision-makers are LafargeHolcim, large oil and gas companies, as well as Members of Parliament and other government officials. CUT also participates in tours hosted by InnoTech at the ACCTC to show how CUT's technology utilizes the resources provided at the test centre.

CUT plans to continue publishing press releases, hosting tours, writing case studies, and has plans to co-author technical papers with commercial partners about concrete results.