LH CO_2MENT COLORADO PROJECT

FINAL REPORT

Version 2

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SUBMITTED BY

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Executive Summary

The objective of project "LH CO_2MENT COLORADO PROJECT" is to accelerate the implementation of a 1.5 million tonnes per year (TPY), and first-of-a-kind (FOAK) at world scale, Svante VeloxoTherm™ carbon capture plant. This project represents a quantum leap to a large-scale facility that will launch Svante's carbon capture technology into the next era of accomplishments and market acceptance. By completing the Front-End Loading (FEL) Feasibility Study Report (FEL-2) for a fit-for-purpose design at the HOLCIM cement plant, located near Florence Colorado, USA, this technology can be proven as the future of large-scale deployment for carbon capture and storage.

This carbon capture plant was designed with the goal of reaching a target of near Net Zero Emissions by capturing 90% of the carbon dioxide (CO_2) emissions from the HOLCIM cement plant and from the boiler which produces steam required to regenerate the adsorbent. Additionally, this project will be leveraging a renewable Power Purchase Agreement (PPA) using solar energy to acquire power at the target price of 0.04 $/kWh or less. In its current configuration CO_2 emissions from the HOLCIM cement plant is around 700 – 800 kg/ton of clinker produced. The proposed new carbon capture plant will allow a reduction of CO_2 emissions to about 100 kg/ton of clinker produced.

The scope of work consists of the process design and capital & operating cost estimation (Class IV) for a total plant capacity of 4,750 TPD of pipeline grade CO_2. The Svante VeloxoTherm™ technology is comprised of a Rotary Adsorption Machine (RAM) for intensified Thermal Swing Adsorption (TSA) using Structured Adsorbent Beds (SABs) and related Balance of Plant (BOP), including CO_2 compression.

Significant challenges across industrial projects worldwide have occurred because of the impacts of the COVID pandemic. Large increases and escalations of equipment and supply chain costs have occurred over the last two years, often increasing the overnight capital costs of projects by 20% to 40%. These levels of financial impacts on capital costs have not been seen in the last two decades and the ability to forecast where the price of commodities and equipment is severely hampered by the challenges and volatility within the worldwide supply chain and labor markets.

The FEL-2 efforts demonstrate the potential for obtaining a Total Plant Cost (TPC) estimate of $383.9MM (cost basis of June 2019 per DOE instructions) and an annual operating cost of $56 MM (for the base case using natural gas price at $2.63/MMBTU). Several options for the CO_2 transport and storage have been investigated with the lower cost scenarios being either utilization of CO2 via an existing pipeline for Enhanced Oil Recovery [EOR] at operational fields in the Permian Basin or potential local sequestration in saline aquifers or storage at the Sheep Mountain facility. The sequestration fees and values developed for the study have a February 2022 cost basis. These options are discussed in more detail later in the report.

The TPC of $383.9 MM is equivalent to a capital intensity of $80,821 $/TPD. The capital cost of the RAM for carbon capture represents roughly 12.8% of the TPC. The capital intensity of the cost the carbon capture unit with the required associated Process BOP comes to $36,800 $/TPD. The Site-Specific BOP and the Site Infrastructure (Areas 3 & 4) add $26,863 $/TPD.) The breakdown of areas and impact of site-specific conditions are discussed later in the report.

A business case (financial analysis) evaluation has been undertaken for the Owner's management review. Recommendations on how best to proceed to the next stage of the project have been conveyed and are documented within this report. This analysis has relied on a detailed and comprehensive Project Financial Model, evaluating the Total Project IRR (after tax, unlevered, and including all forecast 45Q PTCs and 100%

tax efficiency) – the project financial analysis (as opposed to standard TEA analysis) only considered a 12 year plant economic lifetime as a result of 45Q being the sole driver considered at this stage. The Total Project IRR was evaluated across a large number of potential scenarios as described below. The evaluation demonstrated that if the 45Q PTD is increased to $85/MT for sequestration, there are a large number of feasible scenarios which demonstrate economic returns.

Given the near-term potential for increased 45Q tax credit pricing and voluntary emissions credits, this analysis pointed to significant potential realizable economic value for the project.

However, a key finding was that significant work will be required during the next phase to better define commercial and financial terms of electricity and natural gas supply and the CO_2 sequestration which will be critical for the project development organization.

At the conclusion of the Feasibility Study, a transition is required to move the project execution into a formal "Owner-centered" model. As identified in the Next Steps section of this report, Owner driven activities prior to, or in parallel with the FEED study, will help ensure that the appropriate resources and systems for project development, feasibility studies, contractual commitments, and implementation activities occur.

As identified within the DOE capital cost summary and evaluations, there are a number of key economic drivers which can have a significant impact on the financial performance of the project. In order to address this degree of variability in key assumptions, the detailed PFM model was used in conjunction with a custom-written script to simulate more than 10,000 different project financial model scenarios across the following key economic drivers:

- Capital De-Escalation
- Natural Gas Price
- Electricity Price
- CO_2 T, S&M Charge
- DOE Funding Grant Levels
- Plant Operating Rate (onstream factor)

An abbreviated summary of the results of this simulation across these variables, in terms of Total Project IRR, is presented in Figure 1 below. As can be seen from the results of this simulation activity, there are a large number of scenarios for the project which are economically feasible.

Holcim (US) Florence Capture Plant | FEL-2 Project Finance Model Results

Total Project IRR (%)

After Tax, Unlevered IRR earned by the entire Project, including all tax benefits on a cash basis assuming 100% tax efficiency

			CO2 TS&M Charge - $ USD/tonne																	
			$10.00						$20.00						$30.00					
			Capital De-Escalation - % of TOC vs FEL-2 Baseline																	
			-20%			0%			-20%			0%			-20%			0%		
			Operating Rate - % onstream																	
DOE Funding Grant - % of Total Capital (TOC)	Electricity Price - $ USD/kWh	Natural Gas Price - $ USD/mmbtu	90%	85%	80%	90%	85%	80%	90%	85%	80%	90%	85%	80%	90%	85%	80%	90%	85%	80%
50%	$0.02	$2.50	43%	42%	41%	36%	35%	34%	37%	36%	35%	31%	30%	29%	31%	30%	29%	25%	24%	23%
		$3.50	40%	39%	38%	33%	32%	31%	34%	33%	32%	28%	27%	26%	28%	26%	25%	22%	21%	20%
		$4.50	37%	36%	34%	31%	30%	28%	31%	30%	28%	25%	24%	23%	24%	23%	21%	19%	18%	17%
	$0.04	$2.50	39%	38%	36%	32%	31%	30%	33%	32%	30%	27%	26%	25%	26%	25%	24%	21%	20%	19%
		$3.50	36%	35%	33%	30%	28%	27%	29%	28%	27%	24%	23%	22%	22%	21%	20%	18%	17%	15%
		$4.50	33%	31%	30%	27%	26%	24%	26%	25%	23%	21%	20%	18%	18%	17%	16%	14%	13%	12%
	$0.05	$2.50	37%	36%	34%	31%	29%	28%	30%	29%	28%	25%	24%	23%	24%	22%	21%	19%	18%	16%
		$3.50	34%	32%	31%	28%	26%	25%	27%	26%	24%	22%	21%	19%	20%	18%	17%	15%	14%	13%
		$4.50	30%	29%	28%	25%	23%	22%	23%	22%	21%	18%	17%	16%	15%	14%	13%	11%	10%	9%
20%	$0.02	$2.50	29%	28%	27%	24%	23%	22%	25%	24%	23%	20%	19%	18%	20%	19%	18%	16%	15%	14%
		$3.50	27%	26%	25%	22%	21%	20%	23%	21%	20%	18%	17%	16%	18%	17%	15%	13%	12%	11%
		$4.50	25%	24%	23%	20%	19%	18%	20%	19%	18%	16%	15%	14%	15%	14%	13%	11%	10%	9%
	$0.04	$2.50	26%	25%	24%	21%	20%	19%	22%	21%	19%	17%	16%	15%	17%	15%	14%	12%	11%	10%
		$3.50	24%	23%	22%	19%	18%	17%	19%	18%	17%	15%	14%	13%	14%	13%	11%	10%	9%	8%
		$4.50	21%	20%	19%	17%	16%	15%	16%	15%	14%	12%	11%	10%	10%	9%	8%	7%	6%	5%
	$0.05	$2.50	25%	24%	22%	20%	19%	18%	20%	19%	18%	15%	14%	13%	14%	13%	12%	11%	10%	9%
		$3.50	22%	21%	20%	18%	17%	15%	17%	16%	15%	13%	12%	11%	11%	10%	9%	8%	7%	6%
		$4.50	20%	18%	17%	15%	14%	13%	14%	13%	12%	10%	9%	8%	8%	7%	6%	5%	4%	3%
0%	$0.02	$2.50	24%	23%	22%	19%	18%	17%	20%	19%	18%	16%	15%	14%	16%	15%	14%	12%	11%	10%
		$3.50	22%	21%	20%	17%	17%	15%	18%	17%	16%	14%	13%	12%	14%	13%	12%	10%	9%	8%
		$4.50	20%	19%	18%	16%	15%	14%	16%	15%	14%	12%	11%	10%	11%	10%	9%	7%	7%	6%
	$0.04	$2.50	21%	20%	19%	17%	16%	15%	17%	16%	15%	13%	12%	11%	13%	12%	11%	9%	8%	7%
		$3.50	19%	18%	17%	15%	14%	13%	15%	14%	13%	11%	10%	9%	10%	9%	8%	7%	6%	5%
		$4.50	17%	16%	15%	13%	12%	11%	12%	11%	10%	9%	8%	7%	7%	6%	5%	4%	3%	2%
	$0.05	$2.50	20%	19%	18%	15%	14%	13%	16%	15%	14%	12%	11%	10%	11%	10%	9%	7%	6%	5%
		$3.50	18%	17%	16%	13%	13%	12%	13%	12%	11%	9%	8%	7%	8%	7%	6%	5%	4%	3%
		$4.50	15%	14%	13%	11%	10%	9%	10%	10%	9%	7%	6%	5%	5%	4%	3%	2%	1%	0%

Figure 1- Abbreviated Project Financial Model Simulation Results for Key Economic Drivers

Technology Implementation

Svante has developed an energy efficient and low-cost technology for capturing CO_2 from industrial flue gas streams. Svante's VeloxoTherm™ CO_2 capture process is an intensified Thermal Swing Adsorption (TSA) system using advanced Structured Adsorbent Beds (SAB) and a novel process design to capture CO_2 from industrial flue gas streams. The adsorbent is contained in a Rotary Adsorption Machine (RAM) which is the concept at the core of the VeloxoTherm™ technology. The process is capable of producing a high purity CO_2 stream by recovering CO_2 from the flue gases generated by the combustion of fossil fuels.

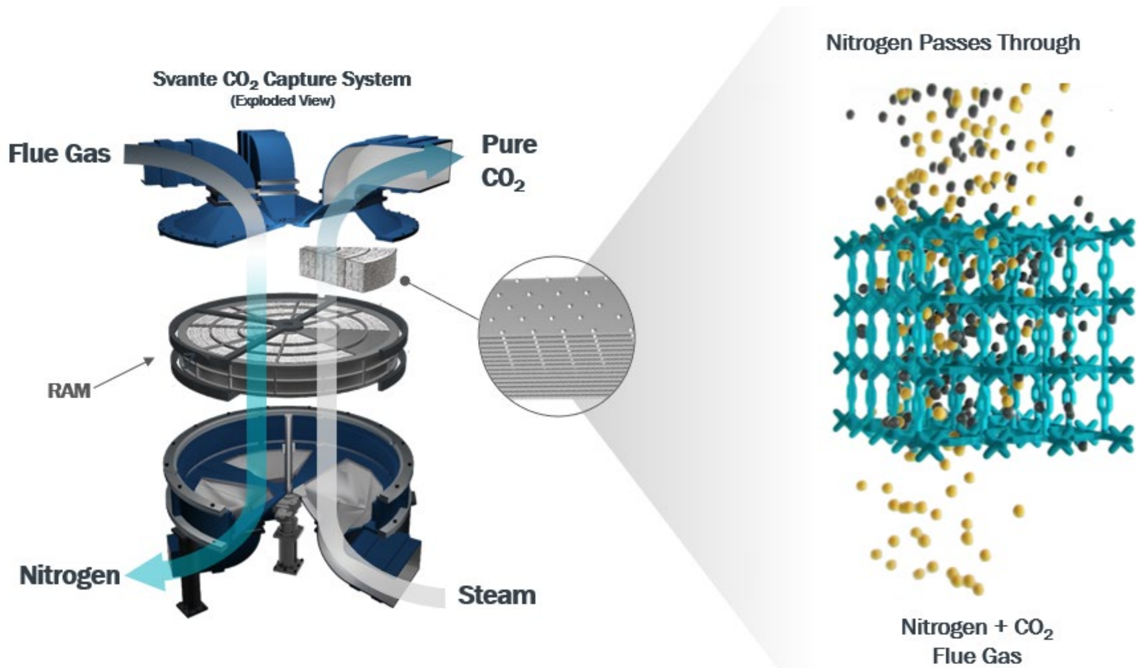


Figure 2 - VeloxoTherm™ Rotary Adsorption Machine

The key to this application is the development of a new class of advanced sorbent materials which are based on Metal Organic Frameworks (MOF) structure. These materials exhibit sharper temperature and pressure swing adsorption and desorption which allow for lower energy loads and faster kinetic rates for process intensification. The proprietary MOF, CALF-20, exhibits unique resistance to SOx, NOx, oxygen impurities and moisture swing and therefore was selected for cement flue gas applications.

Process Design Basis

Tie-In Point

The exhaust gas from the HOLCIM cement plant clinker manufacturing process, which is the feed gas to the carbon capture system, will be taken from the top of the wet lime scrubber as shown as TP-1 in Figure 3. This gas is not mixed with the clinker cooling air to avoid CO_2 dilution in the feed gas to the carbon capture plant, since the clinker cooling air has a very low CO_2 concentration.

Capacity

From a stack data analysis performed in Q4-2020, it was identified that the HOLCIM cement plant would generate approximately 4189 TPD of CO_2 at Best Demonstrated Practice (BDP) conditions, equivalent to about 700-800 kg CO_2 /ton of clinker. This estimation has been used for all the detailed process options investigated in this scoping study.

On-Stream Factor

For the purposes of the Techno-Economic Analysis (TEA) and in this document, it has been assumed that the HOLCIM cement plant will achieve an on-stream factor of 85%. For the financial model, a 90% on-stream factor after the 3rd year of operation has been assumed. These values were coordinated with HOLCIM as the operator of the Host Site.

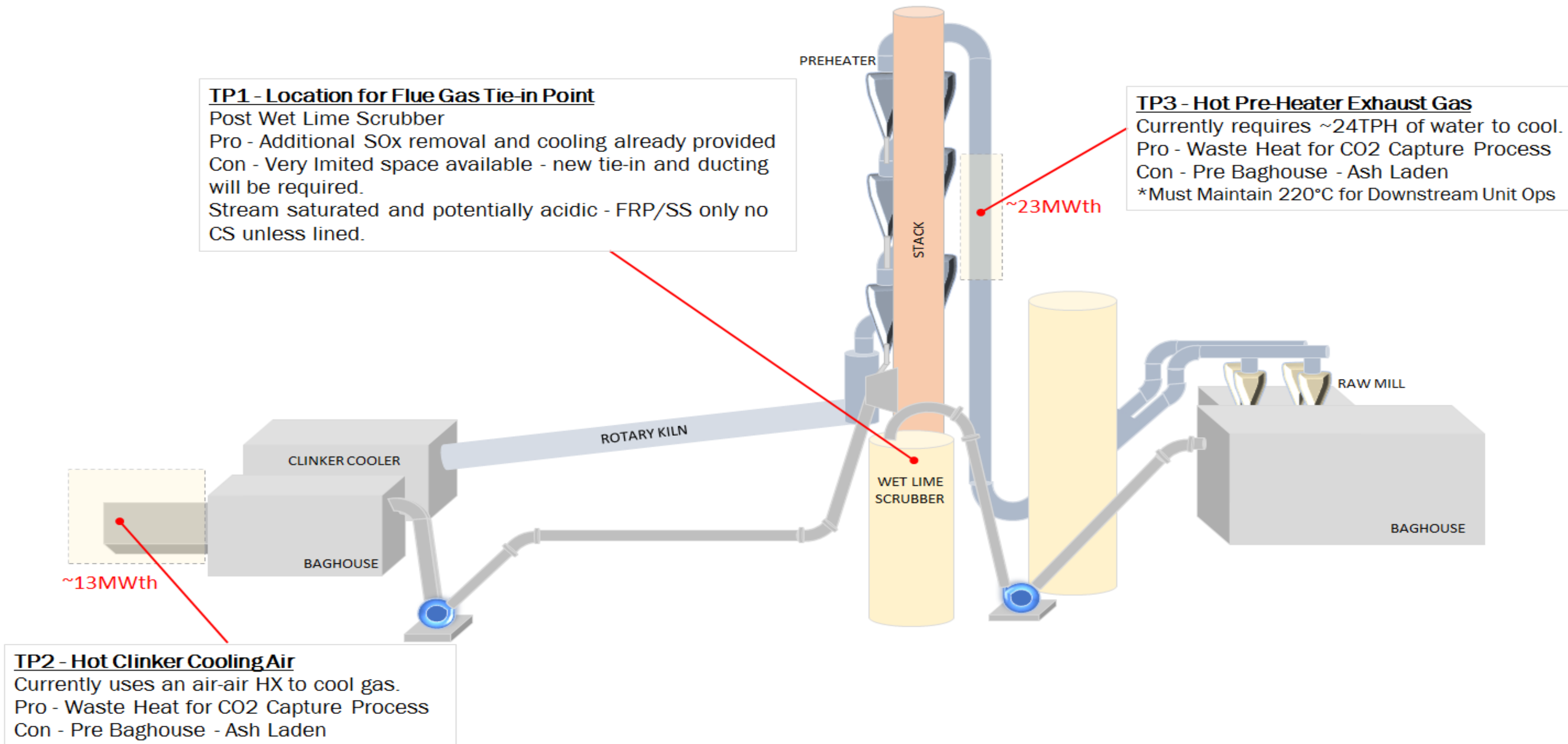


Figure 3 - Cement Plant Tie-In Point (TP) Locations

Holcim utilizes a range of fuels and fuel blends at the facility which include Coke, Coal and natural gas. Depending on the fuel/fuel blend, CO_2 in the flue gas can range from approximately 700 to 800 $KgCO_2$/t clinker.

Waste Heat

Figure 3 also shows two (2) possible locations for waste heat integration. It should be noted that during FEL-1, an option to recover heat from the HOLCIM cement plant was discussed. The use of a Heat Medium Oil (HMO) to recover heat from these locations would be cost prohibitive and create additional environmental risks. For these reasons, and with consensus from HOLCIM as the Host Site owner, the waste heat recovery was not pursued in FEL-2 but could be evaluated further during the FEED stage.

CO_2 Product Specification

Table 1 shows pipeline grade CO_2 product specification.

Table 1 - CO2 Product Specification

CO_2 Product Specification		
Component	**Unit**	**Specification**
Pressure	PSIG	2215
Temperature	F	<120
CO_2 Content	mol%	>95
Water	/MMSCF	<30 lbs
H2S	ppmw	<20
Nitrogen	mol%	<4
Sulphur	ppmw	<35
Oxygen	ppmw	<10
Hydrocarbons	mol%	<5
Glycol	/MCF	<0.3 gal
Carbon Monoxide	ppmw	<4250
NOx	ppmw	<1
SOx	ppmw	<1
Particulates	ppmw	<1
Amines	ppmw	<1
Hydrogen	mol%	<1

Flue Gas Sources to the Carbon Capture Plant

There will be two feed gas sources for the carbon capture equipment. The primary source will be from the cement plant (TP-1 - post wet scrubber) and the additional source will be from the natural gas fired auxiliary equipment required in the capture plant. These sources are combined prior to the main flue gas blower to form the feed stream to the carbon capture facility.

Table 2 - Flue Gas Sources Composition

Flue Gas Sources				
Flue Gas Source	**Unit**	**Cement Plant Exhaust TP-1**	**Natural Gas fired auxiliary equipment**	**Combined Flue Gas Feed**
Flue Gas CO_2 Concentration	%v/v dry	12.95	10.15	12.26
Total CO_2 in Flue Gas	TPD	4189	1086	5275
CO_2 Capture Recovery	%	90	90	90
CO_2 Captured	TPD	3722	977	4750
Capture Plant Design Capacity	TPD	-	-	4750
Composition				
Carbon Dioxide	%v/v	10.64	8.5	10.12
Water	%v/v	17.84	16.24	17.45
Nitrogen	%v/v	65.09	72.06	66.80
Oxygen	%v/v	6.43	3.2	5.64
SO_2 (max 100ppmv)	ppmv	40-50	-	40-50
NOx (NO2 1-2ppmv)	ppmw	200-300	-	200-300

Site Selection & Planning

The carbon capture plant will be sited adjacent to the HOLCIM cement plant, which is located near Florence, Colorado, USA. CO_2 transport will be accomplished by pipeline from the capture site to one of two storage sites that were selected during FEL-2, from the four options considered in FEL-1.

The original scope of this study included selecting one of four storage site options evaluated in FEL-1 for refinement in FEL-2. However, the scope was modified to include the further evaluation of two options; one option that includes utilization of the CO_2 for Enhanced Oil Recovery (EOR) and the other option that includes sequestration without utilization. This modification will allow flexibility to choose the best storage option in the detailed engineering phase of this project, when the value of storage credits, incentives and other economic parameters are expected to be more certain. The scope of these further evaluations was addressed by the participants at no additional cost to the DOE.

The HOLCIM cement plant is located within 54 miles of the existing Sheep Mountain CO_2 Pipeline (SMPL), which provides access to the selected storage options for sequestering CO_2. A new section of CO_2 pipeline would be constructed to connect the carbon capture plant to the SMPL.

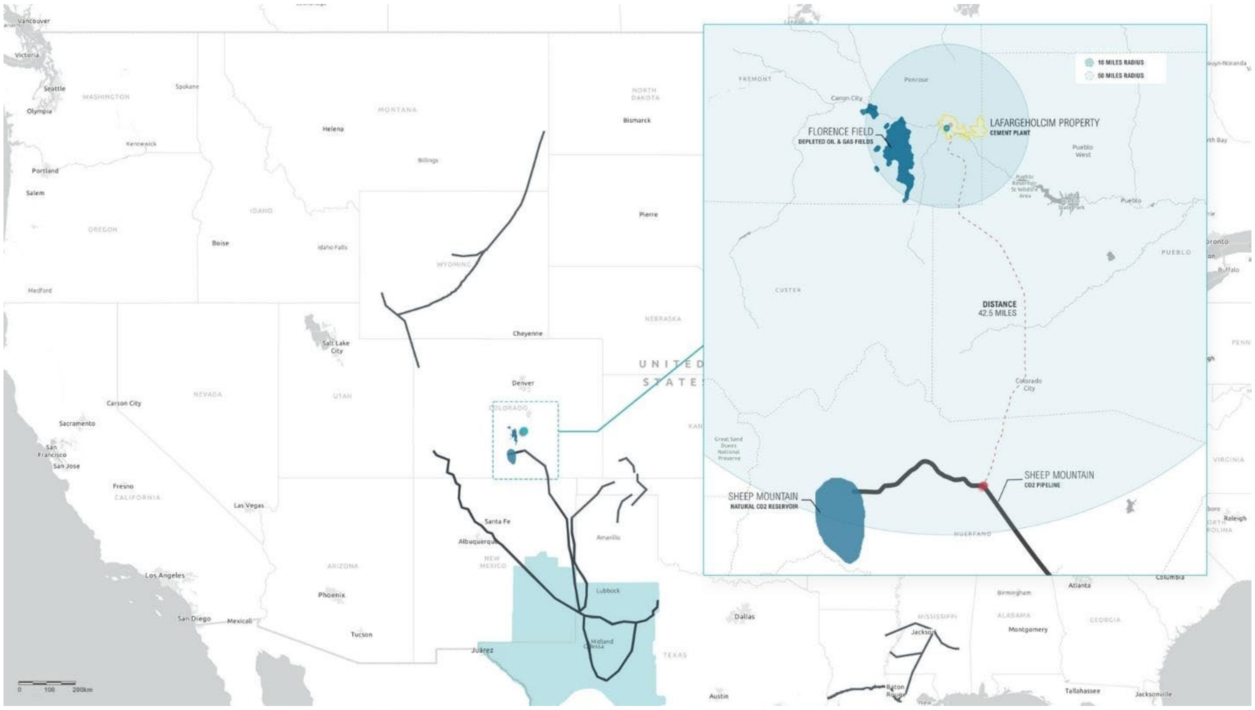


Figure 4 - Map of the HOLCIM Cement plant, Existing Pipelines and two CO2 Storage Location

CO_2 Transport & Storage

The captured gaseous state CO_2 will be transformed into a dense phase for more efficient transport, i.e., reduced pipeline size and cost. This dense phase may be a liquid or a super-critical fluid.

For the LH CO_2MENT COLORADO project, both CO_2 storage options selected for consideration involve the secure and permanent geologic sequestration of CO_2 deep beneath the Earth's surface.

Four storage options were evaluated in FEL-1 as follows:

Option A: Storage in a saline aquifer

Option B: Storage in depleted oil and/or gas fields

Option C: Storage in the Sheep Mountain CO_2 natural source field

Option D: Storage using CO_2 EOR in existing fields

Option D, Storage using CO_2 EOR in existing fields, is the only storage option evaluated that includes CO_2 utilization. This option was therefore selected for further refinement in FEL-2.

Valid storage options that do not include utilization are Option A - Storage in a Saline Aquifer; and Option C - Storage in the Sheep Mountain CO_2 natural source field.

Option C, The Sheep Mountain field presents a high degree of confidence for permanent storage due to its proven ability to store CO_2 for millions of years. The sequestration fee estimates from FEL-1 also showed that the Sheep Mountain field had the most economically attractive sequestration fees of the two non-utilization options. It is for these reasons that Sheep Mountain CO_2 natural field was chosen as the second option for further refinement in FEL-2.

Option A, Additional efforts to further explore the potential for local storage in a Saline Aquifer have resulted in this being a potential storage option but shall be evaluated for viability and financial feasibility in the next phase of the project.

Option B, Storage in depleted oil and/or gas fields, was discarded in FEL-1 due to the absence of depleted oil and/or gas fields within a 50-mile radius of the capture plant.

Figure 5 shows that both selected storage options include a 'new' pipeline that will transport CO_2 from the carbon capture plant to a tie-in point into the existing CO_2 transportation network. The existing routes, 'SMPL West' and 'SMPL South' will transport CO_2 to either the Sheep Mountain CO_2 source field, or to CO_2-EOR fields via the Denver City CO_2 hub.

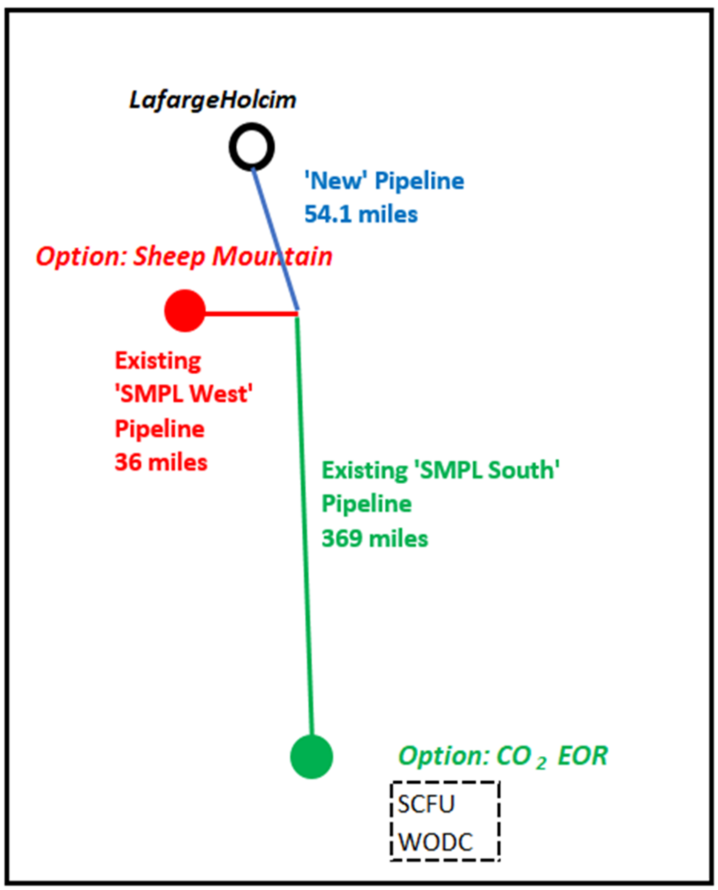


Figure 5 - Map Showing the Pipeline Distance and Location for CO2 Sequestration Options

The Sheep Mountain CO_2 source field is a natural geologic trap that has held accumulations of CO_2 for millions of years. It is largely depleted of natural CO_2 and could be converted into a CO_2 sequestration hub. that can hold up to 75 million tonnes of anthropogenic CO_2, which is equal to the amount of gas that has been voided from the Sheep Mountain field over its producing stage. The field includes 28 existing wells. The assessment calculates that 11 of the existing wells would be converted to UIC Class VI injection wells to inject the CO_2 captured from the HOLCIM cement plant. Some of the remaining wells would be used for monitoring purposes and the remainder would be permanently sealed.

OLCV identified the Salt Creek Field Unit (SCFU) and the Wasson Old Denver City (WODC) unit as two existing CO_2-EOR projects located in the Permian Basin of West Texas that could receive CO_2 via the Sheep Mountain pipeline and provide a combined total secure geologic storage potential of 2 million tonnes of CO_2 per year for a period of 20 years. This volume is over double the amount of CO_2 expected to be captured from the carbon capture plant. The SCFU and WODC unit are existing projects that are very well characterized geologically and have demonstrated the ability to securely sequester CO_2. No additional UIC permits are required as CO_2 is already being sequestered in these EOR projects using existing UIC Class II injection wells. The OLCV information is further discussed in Subtask 3.5.

Environmental & Permitting

There are several permits required for the construction and operation of the carbon capture plant as well as for the CO_2 sequestration at the Sheep Mountain Unit.

Currently, the longest anticipated permit application period is for the National Pollutant Discharge Elimination System (NPDES) permit. This permit could take up to one year for approval following submittal. This duration is reflected in the project schedule (ref. Appendix A-1). An alternative to the carbon capture plant having its own NPDES permit would be to modify the existing HOLCIM cement plant permit, if possible. This will be investigated further in the FEED of the project. Preliminary contact with the applicable agencies was done during the FEL-2 stage. As the project progresses into the next stages, proactive communications with the relevant agencies will help inform on what is the best method to obtain the necessary permits.

The construction and operating permits are presently the critical item on the schedule since a typical project will not commit to procurement of equipment and final engineering until all permit hurdles are out of the way. The impacts on the project development schedule will be further assessed during the next stage of the project with the assistance of the permit agencies.

As outlined further in the report, the establishment of the Owner/Developer entity and roles will help progress the permitting process and relevant submittals.

Additional information on environmental constraints and permitting aspects of the project are found in Subtask 3.6 of this report.

Objectives

The objective of this project is to accelerate the implementation of a 1 million tonnes per year (TPY) or more, and first-of-a-kind (FOAK) at world scale, VeloxoTherm™ carbon capture plant by completing the pre-front-end engineering design (pre-FEED) of a fit-for-purpose design at an existing cement plant. The VeloxoTherm™ technology is comprised of a rotary adsorption machine (RAM) for intensified thermal swing adsorption (TSA) using structured adsorbent beds (SABs). The study will also include optimization engineering for the potential expansion to 2 million TPY that may provide a step-function advancement toward achieving the U.S. Department of Energy's goal of $30/tonne for carbon dioxide (CO_2) capture, transport and storage (CCS). The project will be executed in two phases where first the Recipient will study and select the preferred design options and most advantageous plant capacity (Front-End Loading (FEL)-1 study), and then secondly develop pre-FEED level engineering deliverables for the selected design (FEL-2).

Background

Electricore, HOLCIM, Oxy Low Carbon Venture (OLCV), TotalEnergies, Svante and Kiewit (KSI Alliance) have joined forces to assess the viability and fit-for-purpose design of a First-of-a-Kind commercial-scale carbon capture and storage facility to be located at the HOLCIM Cement Plant near Florence, Colorado, USA, known as the "LH CO2MENT COLORADO PROJECT''. The study plans to assess the cost of a facility designed to capture at least 1 million tonnes of CO_2 per annum (TPY) and up to 1,500,000 tonnes of carbon dioxide (CO_2) per annum (TPY), directly from the HOLCIM cement plant.

This project will feature Svante's VeloxoTherm™ post-combustion carbon capture technology, designed to remove CO_2 from the flue gas of the cement kiln (13% concentration, dry) as well as CO_2 from related auxiliary natural gas-fired equipment (10% concentration, dry). A renewable electricity PPA (solar power + energy storage) is contemplated in order to minimize the project's carbon footprint toward the goal of a net-zero emission cement production.

The obvious destination for the extracted CO_2 is the Sheep Mountain Pipeline, which starts near Walsenburg, Colorado, about 70 miles south of the plant. This 24-inch 400+ mile pipeline could transport up to 9 million tonnes of CO_2 per year to a hub in Denver City, Texas, for use in CO_2 enhanced oil recovery (CO_2-EOR) operations in the Permian Basin. Nonetheless, the possibility of CO_2 injection and storage into deep saline formations and/or depleted oil and gas fields near the cement plant also warrants assessment. A third option under investigation is the feasibility of using the Sheep Mountain natural reservoir as a storage reservoir by reversing the flow of the Sheep Mountain Pipeline.

The purpose of this report is to document the activities, results and findings associated with the pre-feasibility study (FEL-2).

Unique challenges accompanying Svante technology commercialization projects include technology scaling, cost and schedule uncertainty due to the multiple unknowns of a FOAK project. In addition, the Colorado project is an end-of-the-pipe solution to capture CO_2 from an existing cement plant. This retrofit project adds complexity and risks that a greenfield project does not have – from existing equipment limitations to tight spaces for construction and plant documentation accuracy. One of the challenges faced by retrofits is tailoring the approach to minimize the disruption to production of the existing plant – both minimizing downtime and minimizing risks to operations (ex.: blocking a high traffic area). The project team will need to assess, evaluate, and solve many issues related to cost, schedule, operations, maintenance and performance throughout planning and implementation.

Integrated Lean Project Delivery - ILPD

Complex issues and economic challenges throughout project development and implementation are optimally addressed and solved in collaboration throughout the project development and implementation by an integrated team whose goals are aligned, rather than through negotiations across a table with a restrictive contract in the middle. This project requires that all the participants who are essential to the success of the project be sitting at the table early in the process to allow greater access to pools of subject matter experts and a better understanding of probable implications of design decisions.

Project Development Phases

The proposed Stage Gate Process illustrated in Figure 6 is based on a consistent approach for the completeness of scope definition and preparation of study reports during the various stages of the project development in order to have a shovel-ready and financeable project at the time of the final investment decision (FID).

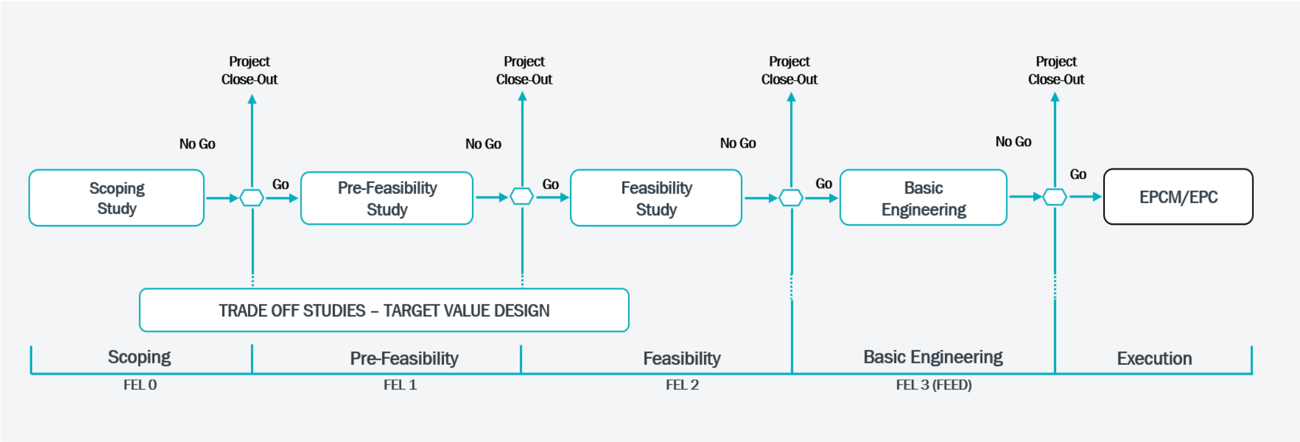


Figure 6 - Stage Gate Process

Pre-FEED Phases

- Scoping Study (FEL-0) - *Complete*
- Pre-feasibility Study (FEL-1) - *Complete*
- Feasibility Study (FEL-2)

FEED Phase

- Basic Engineering (FEL-3 or FEED)

Execution Phase

- Implementation – Detailed Engineering, Procurement, Construction, Commissioning

Throughout each phase and stage gate of the project development lifecycle, the rigor and quality of cost estimates produced will be of critical importance to the success of the project. In addition to standard best practices for estimating and project cost engineering, the proposed approach will require developing high quality cost estimates as early as possible and using a transparent team approach to develop these estimates during the open book FEL phases.

During the FEL-2 stage with a Class IV estimate, a comprehensive project baseline cost estimate has been prepared according to an agreed and complete work breakdown structure and cost breakdown structure (WBS/CBS) that will live through FEL and execution/project controls. This cost estimate has been developed in an integrated and transparent model that all ILPD team members have contributed to. This allows for rapid updating of cost estimates, a real time feedback loop of the impact of design choices and decisions or alternatives regarding scope and schedule. There are benefits in having current and detailed cost estimates available throughout the FEL development phase, as opposed to waiting to create static cost estimates solely for stage gate decisions.

This approach, known as Target Value Design, is focused on designing a detailed budget and focusing on lowering cost estimates throughout the project lifecycle, as opposed to estimating based on detailed designs, when it is time consuming and expensive to reverse design and scope of already made decisions. In addition, an integrated cost model for estimation purposes ensures that members of the ILPD team are providing data-driven inputs on critical aspects of cost and design such as constructability.

At each stage gate, the quality of the definition improves and enables the preparation of the capital and operating cost estimates, with an increasing level of accuracy.

The cost estimating methodology is defined as follows:

- Assessed: Costs based on judgement and general benchmarks when quantities are not available.
- Factored: Proportioned from previous cost data.
- Calculated: Using input from engineering for sizes and quantities.
- Detailed: All quantities calculated, major materials quoted, labor rates/productivity fully calculated or quoted from materials take-off (MTO).

Table 3 - CAPEX Estimate Accuracy Guideline

Project Stage	Scoping	Pre-Feasibility	Feasibility	Basic Engineering	Implementation
IPA Front End Loading (FEL) **AACE Designation (18R-97)** **AACE Usage (18R-97)**	**FEL-0** Class 5 Screening	**FEL-1** Class 4 Initial Study	**FEL-2** Class 4 Initial Feasibility	**FEL-3** Class 3 Budget Authorization	Class 2 Control Budget
Estimate Accuracy Target	-50% to +100%	-20% to +30%	-15% to +20%	-10% to +15%	better than +/- 10%
Project Contigency Allowance	20% to 30%	15% to 20%	10% to 15%	10% to 15%	5% to 10%
Project Defined	0% to 1%	1% to 5%	10% to 20%	30% to 40%	50% to 100%
Estimation Methodology	Assessed	Factored	Calculated	Detailed MTO	Detailed MTO
General Project Data					
Project Scope Description	Preliminary	Defined	Defined	Defined	Defined
Plant Capacity	Preliminary	Defined	Defined	Defined	Defined
Plant Location	Approximate	Specific	Specific	Specific	Specific
Site Conditions	Preliminary	Defined	Defined	Defined	Defined
Integrated Project Plan	Preliminary	Defined	Defined	Defined	Defined
Project Schedule	Level 1	Level 2	Level 3	Level 3	Level 4
Engineering Deliverables					
Block Flow Diagrams (BFDs)	P/C	C	C	C	C
Process Flow Diagrams (PFDs)	S/P	P/C	C	C	C
Discipline Design Criteria	S	P/C	C	C	C
Plot Plans	S	P/C	C	C	C
Utility Flow Diagrams (UFDs)	S/P	P/C	C	C	C
Piping & Instrument Diagrams (P&IDs)		S	P/C	C	C
Equipment List	P	P/C	C	C	C
Electrical Single-line Diagrams (SLDs)	S/P	P/C	C	C	C
Specifications & Datasheets	S/P	P/C	C	C	C
General Arrangement Drawings	S/P	P/C	C	C	C
Mechanical Drawings		S	P	P/C	C
Electrical Drawings		S	P	P/C	C
Instrumental/Control Drawings		S	P	P	C
Civil/Structural Drawings		S	P	P/C	C
Architectural Drawings		S	P	P/C	C

Legend:
Blank: Development has not begun
Started (S): Work has begun; scketches, rough outlines
Preliminary (P): Work on deliverables is advanced, initial review complete
Complete (C): Deliverables has been fully reviewed and Issued for Construction - IFC

Project Schedule levels:
Level 1: Master Schedule
Level 2: Schedule by Work Breakdown Structure - WBS
Level 3: EPC Schedule
Level 4: Contractors, Suppliers Package Schedules

This FEL-2 Report documents efforts and decisions made during the Feasibility phase of the project based upon the requirements DE-FE0031942 SOPO, Task 3.0 and the guidelines of the Association for the Advancement of Cost Engineering (AACE).

Task 1.2 – Technology Maturation Plan (TMP)

The objective of this study was to complete a pre-feasibility level engineering design of a commercial scale CO2 capture plant using the Svante VeloxoTherm™ solid adsorbent CO2 capture technology. The overall system was designed to capture approximately 1,500,000 tonne/year net CO2 with 90%+ carbon capture efficiency at an existing Holcim cement plant near Florence Colorado. The Carbon Capture Facility was designed as an end of pipe facility, with one main flue gas tie in at the outlet of the Kiln wet lime scrubber.

The study included optimization engineering for a facility that may provide a step-function advancement toward

1) contributing to and validating key aspects of the technology roadmap established by the U.S. Department of Energy (DOE) to approach achievement of DOE's performance goals of CO2 capture with 95% CO2 purity at a cost of $30/tonne of CO2 captured, for a coal power plant, among other cost goals, by 2030,
2) advance the commercial viability of the RAM technology at DOE targets,

3) accelerate the application of post-combustion CO2 capture to flue gas streams from power plant and industrial sources, and
4) identifying important design and project execution opportunities to be evaluated during the next, FEED phase of commercial project development.

In accordance with the description of the DOE Technology Readiness Levels (TRL), all subsystems for Svante carbon capture system are currently at TRL 5 – 6. Several of the unit operations utilized in the Svante process are well proven, commercially available at TRL 9. Data for the study was made available from five sites comprising three Process Demonstration Units (PDU) of 0.5 TPD or less which currently test a variety of adsorbents and flue gas constituents, one 1 TPD Pilot Plant unit installed and operating at an existing cement plant in Richmond, BC and one engineering scale facility rated at 30 TPD capture capacity treating flue gas from a natural gas fired steam boiler.

Svante test units use several adsorbents including a CALF-20 MOF sorbent material which is expected to be utilized for commercial scale cement facilities. This sorbent is currently installed and operating in one PDU and the 1 TPD pilot unit installed at the cement plant. In addition, construction of a second of a kind (SOAK) engineering scale capture plant of 25 TPD capture capacity utilizing CALF-20 adsorbent is nearing completion at a facility in California. This unit will undergo a series of tests that will represent the range of conditions expected in a full-scale operating environment. It should be noted that the SOAK demonstration unit in California incorporates recent process improvements which will result in an increase in CO2 product purity to better than 95% on a dry basis.

Svante estimates that to meet the demands of the market, single RAM units will be required with capture capacities of approximately 500 TPD, and 2000 TPD. To achieve this level of scale-up, Svante have initiated a RAM design using a toroid bed arrangement. The advantage of this design is that the RAM will use standard Structured Adsorbent Bed (SAB) modules derived from the current bed element design. This approach will simplify/standardize manufacturing and allow an accelerated path to unit scale-up. The modular design is also expected to yield cost benefit in both manufacturing and construction phases of commercial projects.

Svante has initiated a collaboration and development agreement for CALF-20 MOF adsorbent powder from the world leader in the manufacturer for MOF materials, BASF Catalysts (BASF). This collaborative work has resulted in the production of CALF-20 at a representative batch size for scale-up (minimum 300kg batch size) for the California based capture plant.

Svante's existing 21,000 sq. ft low volume manufacturing facility in Burnaby, BC has a pilot line capable of producing the novel SABs at a rate of ~ 40,000 tonnes equivalent CO2 removal capacity per year. Svante is currently expanding capacity at a new manufacturing facility which will be capable of producing ~ 10,000,000 tonnes CO2 removal capacity per year. The new SAB manufacturing plant will be operational by mid-2024. Future scale up beyond 2024 will depend on market demand and will require the addition of new manufacturing facilities either through direct company expansion or new manufacturing alliances.

By the end of 2022, it is expected that the Svante R&D and testing program will benefit from operational data collected at 6 facilities, three process demonstration units of 0.5 TPD or less [varying bed design and flue gas characteristics], a 1 TPD pilot unit at an existing cement plant and two engineering scale units operating on flue gas from natural gas fired facilities. A Demonstration "Buck" [a full scale 14m diameter RAM] will also be constructed by Q1-2023. This combination of test facilities will be used to confirm R&D and performance improvement over current levels. The improvements will be achieved through optimized manufacturing techniques, next generation materials plus enhancement of bed design and kinetics which will be used to optimize the VeloxoTherm™ cycle.

Post-project efforts to attain the next level, TRL (7), include project planning, specification, completed designs, permitting and fundraising for a specific industrial facility at full scale. These tasks were not included in this study because they require fundraising and significant commercial investment at an existing industrial facility outside the scope of DOE supported projects.

Task 3.0 – FEL-2 Feasibility Study

Details of the required estimation and summaries of the efforts to achieve the estimates are provided in the following subtasks.

Subtask 3.1 – Design Criteria

One location at the host site and one *BoP* approach will be selected based upon performance, then cost, then location and proximity to feasible storage. The capital cost, updated from FEL-1 to reflect the advanced project definition and optimization, is detailed under Subtask 3.7.

Power and Natural Gas Supply

The LH CO_2MENT COLORADO carbon capture project will tie-in to an existing utility115kV power transmission line that runs near the site. The 115kV supply will be stepped down to an intermediate voltage via a large capacity main transformer and then distributed to the load centers around the site via a medium voltage switchgear line-up. A large part of the medium voltage distribution will be achieved via underground duct bank to power distribution center enclosures located throughout the site. Once the voltage reaches the electrical enclosures around the site, it will be stepped down to 6.9kV and 480V and then distributed to the equipment drive motors, heaters, lights, and power receptacles.

During the FEL-2 process, the team honed the power demand for the carbon capture plant using historical data as well as real-time manufacturer quotations for equipment sized exactly for HOLCIM cement plant requirements. Removing the Air-Cooled Heat Exchangers (ACHEs) and using a cooling tower was just one example of how the team worked to reduce key operational expenses. Variable Frequency Drive (VFD) consideration, as well as pump redundancy and efficiency were also considered.

Currently, power requirements for the HOLCIM cement plant are estimated to be approximately 40MVA. This project estimates an additional 76 MW of connected load power requirement. Assuming a 0.85 pf, this puts the total demand at approximately 131 MVA. The maximum power rating for the transmission system interconnect is currently 119 MVA. During the next phase of the project, further discussions with the local utility shall occur to evaluate the potential reconductoring of the current line or other cost-effective options to supply the required electrical service to meet the connected loads.

The Fuel Gas System (FGS) will be supplied from a regional natural gas supplier at tie-in connection point TP-3. The tie-in is located at the existing fuel gas header located near the north side of the HOLCIM cement plant. The interconnecting pipeline is 8-inch and normally operates at 678 psig. Fuel gas will be routed through a new header from the tie-in point to the carbon capture plant to supply the Low-Pressure Steam (LPS) boilers and other auxiliary heaters. The FGS system shall be designed to measure fuel gas flow rate and to regulate the gas pressure for use by the boilers and heaters.

Renewable Electricity

A proposal for a 250 MW DC solar photovoltaic and battery energy storage system was considered as a source of renewable energy to supply power to the project. As an alternative renewable option, a proposal for on-site distributed generation wind project was considered. Either renewable energy projects would be executed under a Power Purchase Agreement (PPA) net metering program at an expected $40 per MWh or less. The Solar PV and battery energy storage system was selected for the study because it is projected to produce 100% of the annual electricity demand of the carbon capture plant (~76 MW), reducing the facility dependence on fossil fired electrical power generation. The solar option also requires a smaller land footprint than a wind generated power option.

Net Metering

It is expected that a Solar PV system would participate in the utility's net metering program where exported generation will be credited at near retail rates of energy supply in periods of time where solar production is greater than coincidental on-site load. Over an annual period, the accounting of net energy with the utility would be expected to be nominal while the project would retain the renewable attributes or renewable energy credits (REC's).

The renewable project would qualify for net metering if two (2) criteria are met. First, the generating facility must be sized to supply no more than 120 percent of the customer's average annual electricity consumption at the site. Second, the rated capacity of the generating facility cannot exceed the customer's "service entrance capacity," which is defined as "the capacity of the utility's electric service conductors that are physically connected to the customer's electric service entrance conductors." Further evaluation will be conducted in the FEED phase to determine if the generating facility is sized appropriately to qualify for net metering program in Colorado.

Site Area

The solar and battery storage system may be located in close proximity to the carbon capture plant and within the same property ownership area as the HOLCIM cement plant. The system is expected to be located entirely in Pueblo County near the Fremont County boarder in Colorado. The site location benefits from a viable global horizontal irradiance (GHI) of 1,873.1 kWh/m². The system is expected to occupy approximately 950 acres of surface area, which may include the entire fenced in area of the Solar PV system.

The Solar PV system will be integrated with battery energy storage as a complete system with a single behind the meter point of interconnection to the carbon capture plant. Figure 7 illustrates the conceptual design.

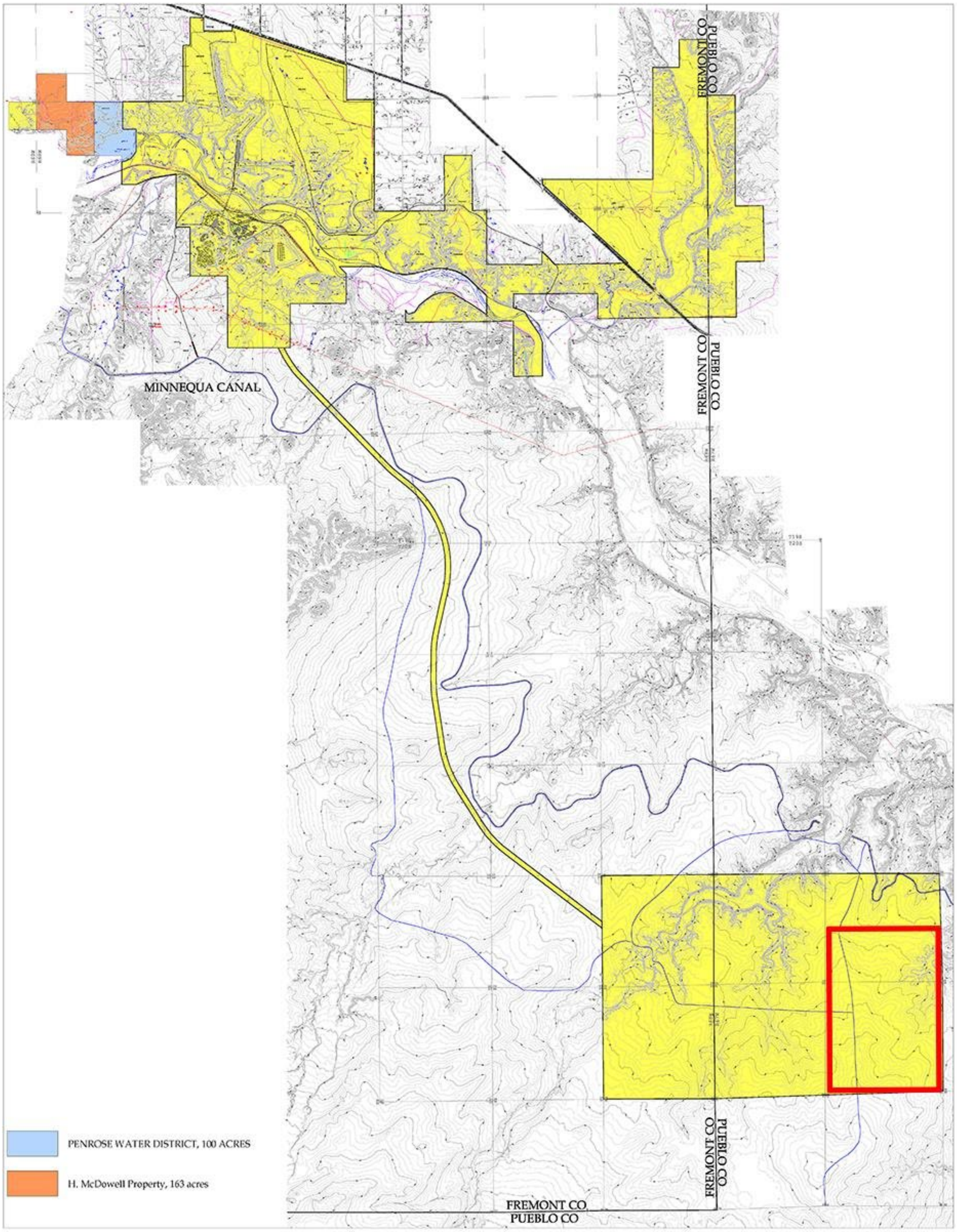


Figure 7 - Preliminary PV & Energy Storage System Location

The battery energy storage system will charge from solar production and discharge daily to manage demand charges. This battery operational algorithm will apply machine learning logic to adapt to historical, current and expected solar production and changes in facility load to effectively manage demand charges during the 1pm-7pm peak period. Due to the daily intermittency and seasonal variations in solar production and the expected steady demand levels of the carbon capture project being approximately 76 MW AC, there will still be some material demand charges during the peak demand period from 1 PM to 7 PM, Monday through Friday. The proposed solar and storage systems are estimated to reduce 90% of demand charges at the site on an annual basis. During the FEED stage, if a solar power system is selected, a revision of capacity will be evaluated.

Water Treatment & Recycling

Carbon Capture Plant Water Balance

Make up water was identified as a critical resource for the carbon capture facility at this geographical location.

The major uses of water at the HOLCIM carbon capture plant will be for cooling tower makeup, demineralized water treatment, boiler blowdown, quench water, miscellaneous station uses such as pump seals and area washdowns, and for potable and sanitary water as shown in Appendix J-3.

FEL-2 evaluated several strategies to reduce the net water usage of the carbon capture plant. The selected strategy assumed that a water trade philosophy between the carbon capture plant and the cement plant can be established. This "trade" sends carbon capture plant clear-well tank effluent to the cement plant back-end processes. In return, the cement plant provides raw water from the existing intake to the carbon capture plant.

Prior to the plan for a water trade between the facilities, the FEL-2 team thoroughly examined various ZLD and wastewater volume reduction treatment plans. After establishing the high costs associated with these options, it was clear that the appropriate path forward to pursue during the FEED stage would be the symbiotic water trade approach. Details regarding cement plant demand, quality requirements, and available water for the carbon capture plant will continue to be validated in the FEED stage to ensure this trade approach is the best path forward. Should the HOLCIM cement plant not be able to accept all of the water produced at the carbon capture plant, additional equipment may be required to treat the remainder of the water so that excess can be discharged for other uses or to a water catch basin.

In the absence of comprehensive water quality information from both the river water source and the HOLCIM cement plant, FEL-2 has assumed that the cooling tower will operate at cycles of concentration (COC) of 3.0. This establishes an expected maximum net water usage for the carbon capture plant, and amount of water available for trade with the HOLCIM cement plant. For any case, the amount of raw water drawn from the intake would remain constant, while varying the quantity of water forwarded from the cement plant to meet the carbon capture plant demands. During the FEED stage, empirical water data and cement plant quality requirements will be validated, and equipment selection will be optimized to reduce operational expenses to the fullest extent possible.

Table 4 - Summary of carbon capture plant demand and return to cement plant for select tower COC operating cases

Tower Operating COC	Carbon Capture Plant Demand (gpm)	Return Water Amount (gpm)
3.0	3835	1553
5.0	3266	985

8.0	3022	741

Site ambient conditions, reduction in power demand and to reduce overall footprint led he study team to limit the use of air-cooled heat exchangers for heat rejection. A single multi-cell cooling tower was selected for the study. This allowed the net water usage for the carbon capture plant to be established and compared to the available water from the local water district. The water mass balance was developed with a single cooling tower operating at a COC of 3.0, which resulted in a net water usage of 3835 gpm for the carbon capture plant.

Additional assumptions resulted in limiting the amount of makeup water treatment equipment required for the carbon capture plant. The water has sufficient hardness and alkalinity such that it is not corrosive, as well as limited chlorides such that carbon steel is an acceptable piping material. Iron, manganese, solids, and organics are suitable for direct feed to the demineralized water treatment ion exchange process without extensive pre-treatment, and other constituents are limited to within EPA National Primary Drinking Water Regulations. The water is suitable for service/fire water use without any treatment, except for a small hypochlorite feed to prevent biological fouling throughout the service/fire water system. During the FEED stage, it will be imperative to assess all constituents of planned water intake sources and condensed water streams, and to ensure all constituents meet the potable and demineralized water minimum requirements, to solidify the design of water treatment equipment.

It is assumed that potable water treatment will not be required. The potable water at TP-8 is assumed to meet EPA National Primary Drinking Water Regulations.

Primary consumers of demineralized water will be the hydrogen electrolysis process, auxiliary boiler makeup, and TEG gas saturator. Quality requirements will be defined for each user during the FEED stage. High-quality makeup to limit boiler blowdown to 1% of the steaming rate minimizes water losses and is considered sufficient quality for the electrolysis process. Hence, water quality requirements for these users will be per EPRI “Comprehensive Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs)”, 2013, as follows:

Table 5 - Chemical composition criteria for demineralized water

Parameter	Value
Sodium	≤ 2 ppb
Sulfate	≤ 2 ppb
Chloride	≤ 2 ppb
Silica	≤ 10 ppb
Total Organic Carbon	≤ 100 ppb
Specific Conductivity	≤ 0.1 µS/cm

The low total dissolved solids (TDS) in the supply water makes ion exchange a good candidate for removing constituents to these levels. Upstream cartridge filters and granular activated carbon vessels will remove any small amounts of solids and organics. To minimize capital expenditures, the cartridge filters, granular activated carbon, and ion exchange vessels will be located on a single portable trailer and switched with a replacement trailer when the ion exchange resin is exhausted.

FEL-2 design divided the carbon capture plant condensate into two (2) categories, each requiring different levels of treatment. High purity (clean) condensate from the RAM, product gas separators, and compression train are collected in a common condensate tank. FEL-2 has assumed the Direct Contact Cooler (DCC) condensate will contain metals and particulates from the flue gas. These contaminants will require different treatment operations compared to the clean condensate. Keeping the condensate streams separate will protect the clean condensate from unnecessary contaminants expected in the DCC condensate stream, simplifying the treatment to a polishing style treatment. Polishing of the clean condensate will be required to remove contaminants, making it suitable for return to the auxiliary boiler and minimizing wastewater discharge and subsequent makeup treatment.

The primary contaminants of concern are carbon dioxide, alkalinity, organics, iron, hardness, and free mineral acidity. A majority of the carbon dioxide will be removed upstream of the condensate treatment via a mechanical degasification process. The condensate will subsequently pass through a cartridge filter followed by a three (3) or four (4) bed ion exchange process. To minimize capital costs, the cartridge filters and ion exchange vessels will be mounted on portable trailers and switched with replacement trailers when the resin is exhausted. Depending on the flow rates that will be validated in the next FEED stage, two (2) or three (3) service trailers may be required at one time.

Under the assumption that the DCC condensate will have high levels of metals and particulates, FEL-2 analysis led to direct DCC blowdown to the Wastewater Equalization Tank, where it will be combined with cooling tower blowdown and treated prior to being sent to the cement plant. The Wastewater Treatment System (WWT) is comprised of softening clarifiers, a thickener, a filter press, intermediate sumps for recycle and associated solid and liquid chemical feeds. A softening clarifier was selected due to elevated hardness levels in the cooling tower blowdown. It is also expected that some of the metals carried over from the DCC will be converted into solid metal compounds in the softening clarifier and be precipitated out with the softened sludge. The thickener further increases the solids content of the softening clarifier underflow, overflow of which is recycled back to the clarifiers. A filter press will be required as a final dewatering step for the thickened sludge. The filter press cake will be collected in a dumpster for off-site disposal, while filter press filtrate will be collected and recycled.

Another key difference between the FEL-1 and FEL-2 designs is that the DCC condensate is not being recovered for demineralized water. This is due to the level of processing required to convert DCC condensate to demineralized water. While treatment of the service water by ion exchange trailer remains the favourable candidate for the demineralized water treatment system, additional trailer(s) will be required to maintain the necessary amount of makeup flow to the demineralized water storage tank.

Figure 8 provides an overview of the carbon capture plant water systems. This drawing assumes that a cooling tower is used for plant heat rejection. If water were not available, water-to-air heat exchangers or a hybrid system would have been required to cool the process streams.

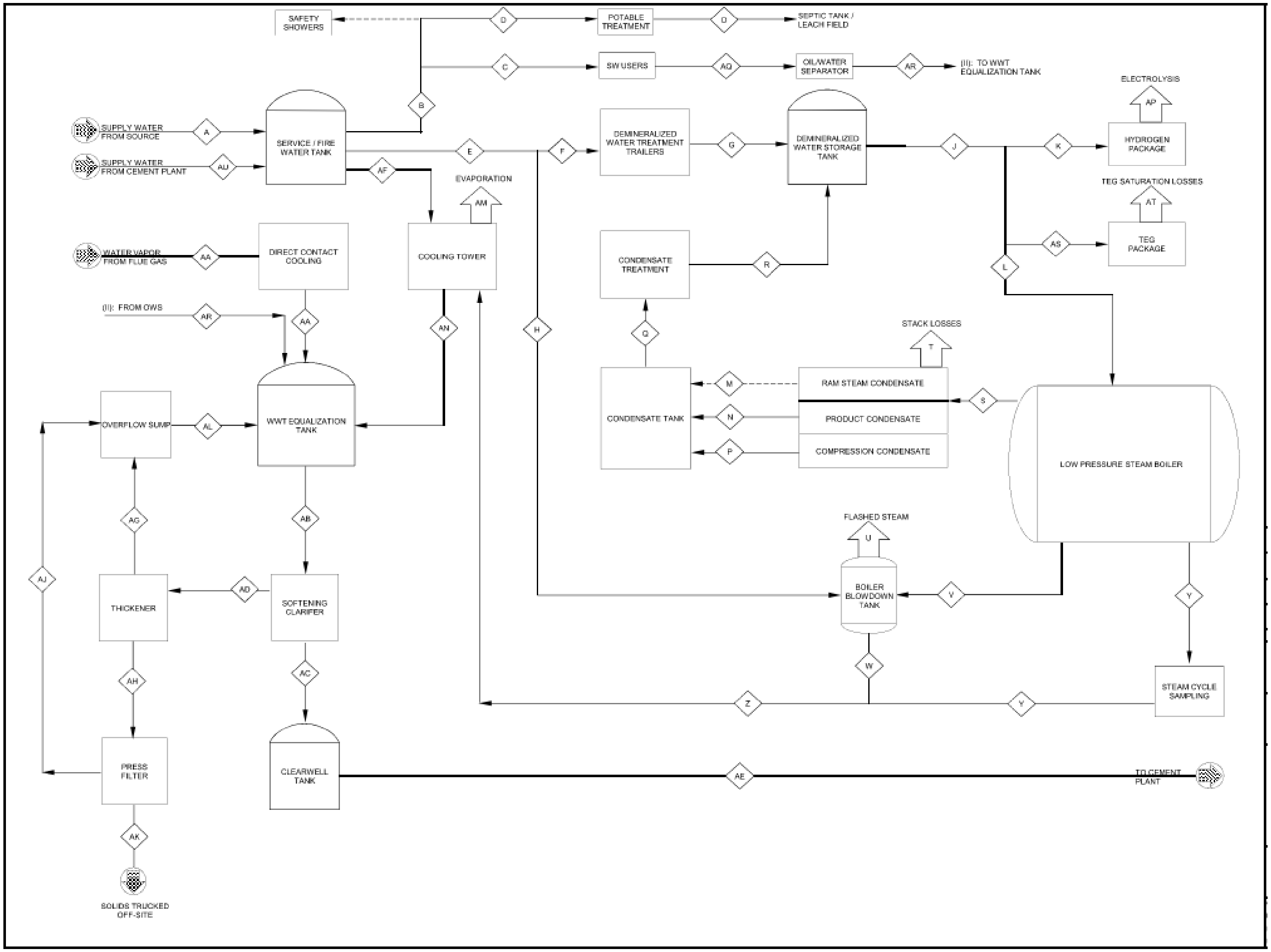


Figure 8 - Water Mass Balance Process Flow Diagram

Process Modeling

3D process modeling for FEL-1 was not extensive. Some 3D models were generated to establish spacing and pipe lengths for the estimate. In FEL-2, the plot plan (Appendix D) and site plan (Appendix E-3) were iterated multiple times to optimize pipe routing in the plant, reduce civil cut and fill volumes, and provide more economical equipment arrangements. 3D modeling of the pipe rack in FEL-2 was also used to optimize flue gas duct and rack steel quantities. Below are a few examples of the layout improvements generated during FEL-2.

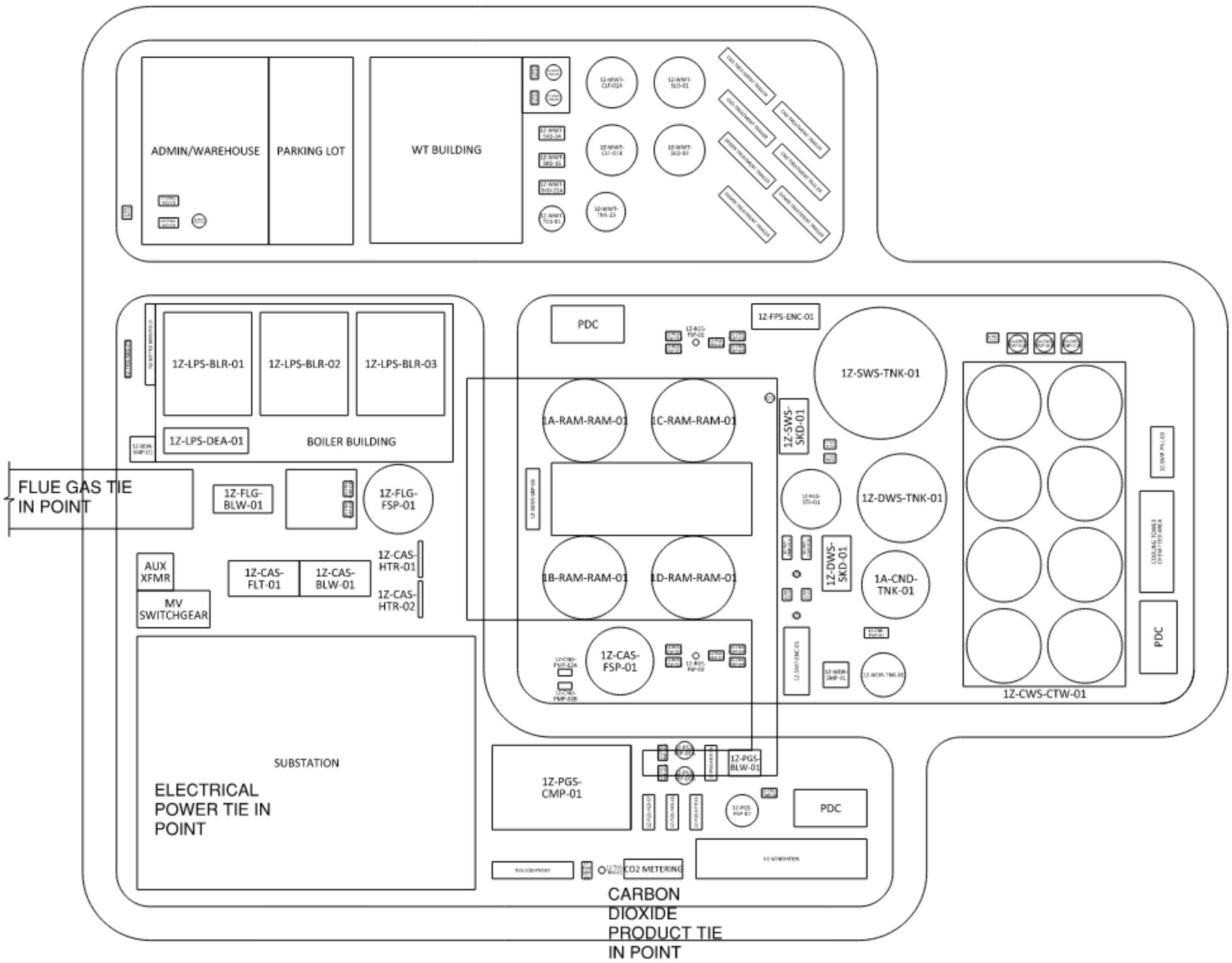


Figure 9 - Carbon capture plant layout, optimized during FEL-2

The following steel models are preliminary and created for the estimate. The final steel structures will be integrated into the plant's final design.

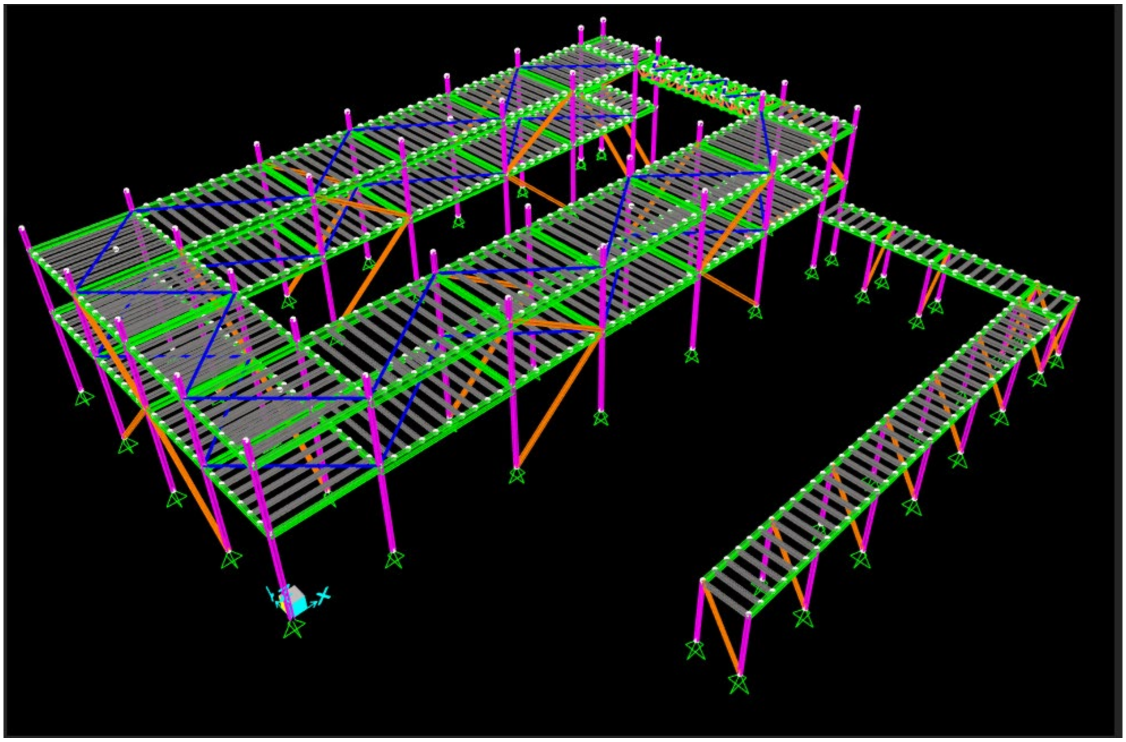


Figure 10 - Rack steel encompassing RAMs.

All four (4) RAMs will be encompassed by this rectangular steel rack which supports each RAM's inputs and outputs.

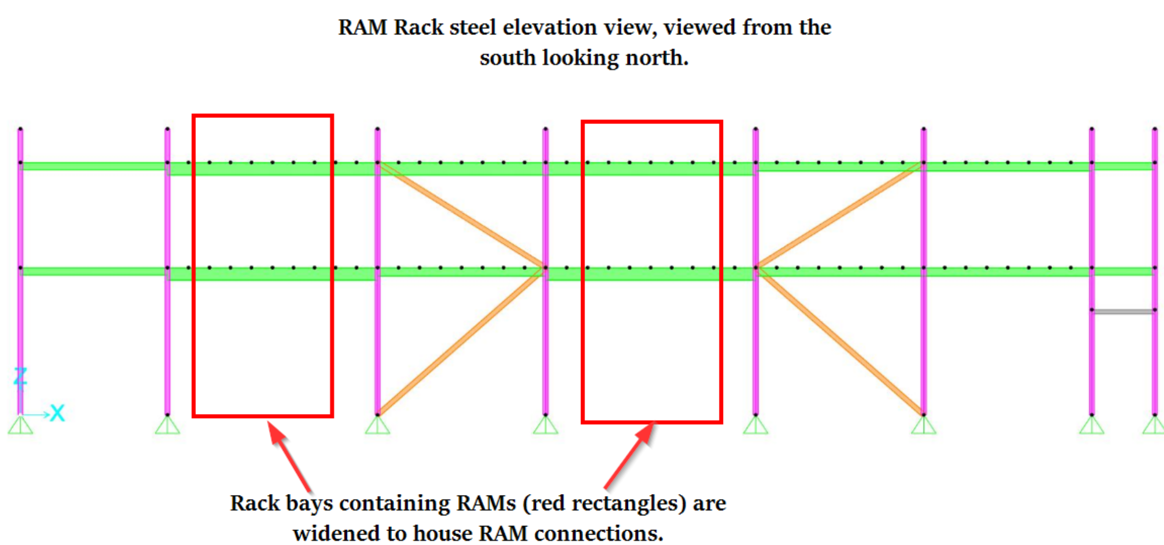


Figure 11 - Rack steel encompassing RAMs.

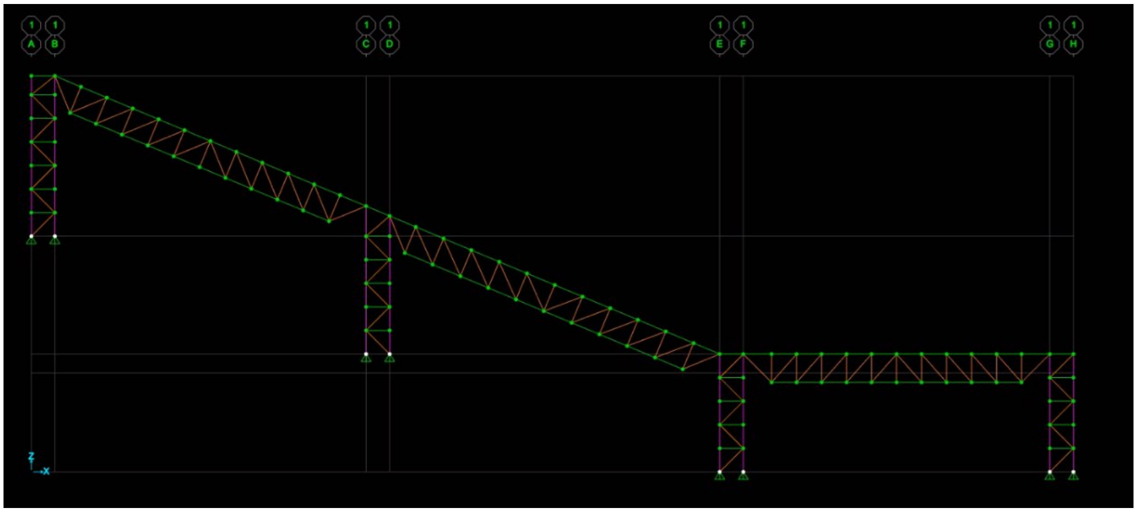


Figure 12 - Steel rack carrying flue gas ductwork from cement plant (right side of image) to the higher elevation carbon capture plant area (left side of image)

The basic modeling within SmartPlant completed for FEL-2 was intended for estimators and engineers to conceptualize the carbon capture plant and highlight aspects that require attention and assist with the development of material takeoffs. Further 3D model development will be performed in the FEED and detail design phases of the project.

Battery Limits

A preliminary process technology package was completed that includes deliverables for the Inside Battery Limits (ISBL) and Outside Battery Limits (OSBL) and deliverables will be further refined during the FEED study.

- ISBL is defined as all equipment and associated components (piping, etc.) that act upon the primary feed stream of a process. ISBL is functional-based and refers to equipment and other components that are solely dedicated to a single process whether or not the equipment is physically located within the geographical boundaries of the unit.

OSBL is defined as utilities, common facilities, and other equipment and components not included in the ISBL definition. OSBL refers to systems (equipment pieces and associated components) that support several units. Typical OSBL equipment includes cooling towers, water facilities, tanks farms, etc. The overall site arrangement will be outlined on the plot plan, including all major equipment, the existing plant, tie-in points, and site roadways. The basic battery limits of the carbon capture plant for the scope of this study are shown in Figure 13 below.

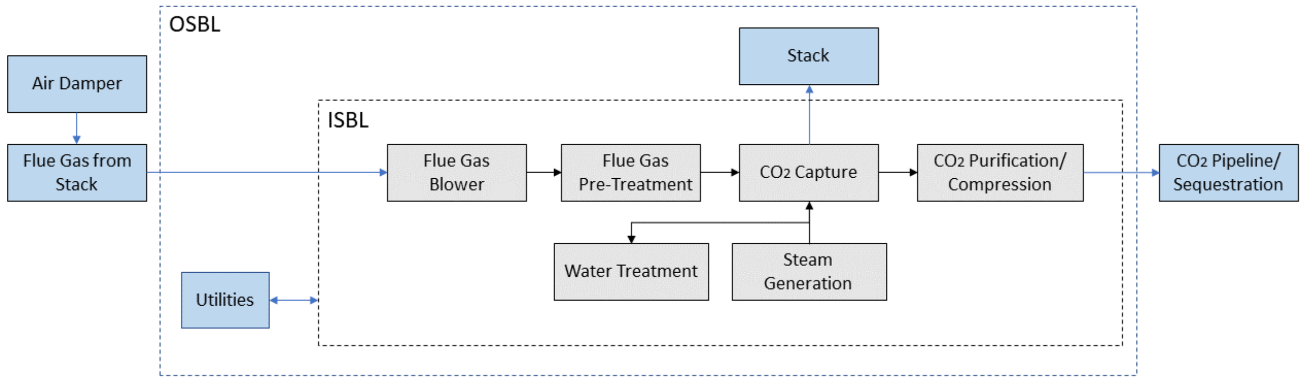


Figure 13 - Carbon capture plant battery limits.

Subtask 3.2 – Process Inside Battery Limit (ISBL)

Process Description

The Svante process is an intensified thermal swing adsorption (TSA) process that uses a patented architecture of structured adsorbent and a novel cycle design and embodiment to economically capture CO_2 from industrial flue gas streams. The process cycle has three (3) major steps: adsorption, regeneration, and conditioning.

Additionally, the inlet flue gas requires conditioning. The flue gas temperature must be adjusted for the adsorbent to be most efficient. This heat removal is normally achieved through a Direct Contact Cooler (DCC) which will also scrub some contaminants from the flue gas.

Adsorbent

Svante has developed a unique Metal Organic Framework (MOF) sorbent designated as CALF-20. This sorbent has high CO_2 adsorption capacity, high CO_2/N_2 adsorption selectivity, fast kinetics, high water tolerance, low regeneration energy and high tolerance to SOx, NOx and O_2, which makes it ideal for cement applications. A recent publication at GHG-15 in Abu Dhabi on the development and testing of this novel MOF sorbent CALF-20 material at HOLCIM Richmond cement plant in British Colombia, Canada, is available in Appendix E-1.

Process Cycle

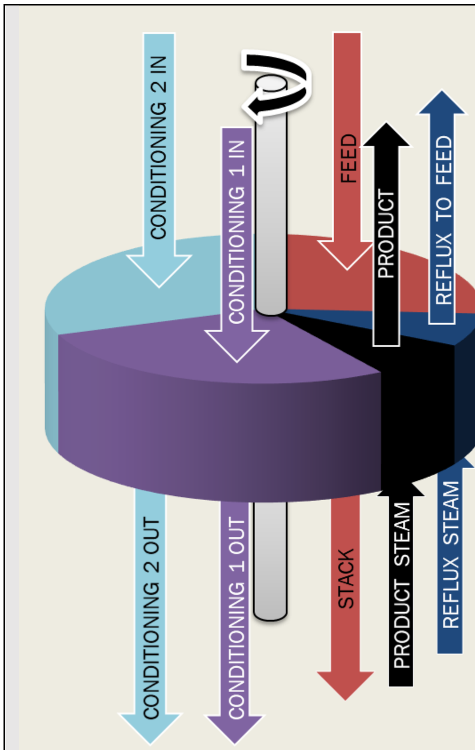
The Svante VeloxoTherm™ process consists of a series of steps which include: passing flue gas, regenerating steam, and conditioning air through the structured adsorbent beds in a specific order. This is accomplished by rotating the adsorbent beds past openings that sequence and time each operation.

i. **Adsorption:** The first step of the process is the introduction of the feed gas into the top of the Structured Adsorbent Beds (SAB), where CO_2 is adsorbed onto the surface of the adsorbent while the remainder of the flue gas – mainly N_2, O_2 and H_2O – is sent to the stack.

ii. **Regeneration:** The CO_2-rich SAB then rotates to a sector of the process where low pressure steam is injected into the bottom of the beds – requiring only a small amount of superheat to overcome heat losses from the system. This step utilizes steam to regenerate the adsorbent and releases a stream composed primarily of CO_2 and steam. This stream is later dehydrated to yield a product gas of 95% CO_2 and less than 30 lbs of water per million SCF.

iii. **Conditioning:** After regeneration with steam, the SAB rotates through a sector of the process where heated ambient air is used to condition and cool the structured adsorbent. The hot ambient air flowing from top to bottom of the SAB – termed Conditioning 1 and Conditioning 2 – remove any residual water vapor from the adsorbent and are required to be sufficiently warm to avoid water vapor condensation. As water vapor desorbs, cooling of the SAB is also achieved and it is ready to start the cycle over again.

For this application, the Svante VeloxoTherm™ process uses a rotating adsorbent contactor with a 5-step cycle to execute the adsorption, regeneration and conditioning functions as shown in Figure 14 below. The adsorbent material is secured within a rotating cylindrical frame, known as a rotary adsorption machine (RAM). The construction of the RAM is based on a technology similar to that of regenerative air heaters, widely used in coal power plants. The frame is divided into distinct sealed zones to allow for the adsorption, regeneration, and conditioning steps.



Step	Cycle	Purpose
1	**Feed & Stack** (Plus Reflux Gas)	Adsorption of CO_2 from the flue gas. Gases, primarily N_2, O_2 and H_2O, are exhausted to the stack after CO_2 has been adsorbed from the Feed.
2	**Steam** (Plus Reflux Step)	A Steam push regenerates the adsorbent and pushes out the high purity CO_2 product. (A reflux steam step allows for higher purity CO_2 to be produced. (*TBD in FEL-2*))
3	**Product**	High purity CO_2 product and moisture are produced.
4	**Conditioning 1**	Heated fresh air is used to remove residual moisture and to cool down the bed for adsorption. A portion of the Conditioning 1 leaving the RAM is recycled to the Steam Step as Waste Heat.
5	**Conditioning 2**	Heated air is used to remove residual moisture from the bed in addition to providing extra cooling to the bed, rendering it ready for the cycle to restart.

Figure 14 - 5-Step Svante Process Cycle

Process Flow Diagram and Tie-in Points

The carbon capture process flow starts from the HOLCIM cement plant flue stack, transits via a large duct to the Svante carbon capture plant, where CO_2 is captured and compressed for safe storage via pipeline. The process uses temperature and pressure to create a dense phase CO_2 stream. The nitrogen remaining after CO_2 separation from the flue gas is exhausted to the atmosphere. The following Process Flow Diagrams (PFDs) [Figures 15 through 19] demonstrate the arrangement of key systems developed during FEL-2.

The PFDs shown below detail the processes around the four (4) RAMs, one (1) BOP train and one (1) CO_2 compression and purification train, designed to capture approximately 4,750 TPD of CO_2. The design also includes reflux systems. This path forward was selected after FEL-1 evaluations to maximize economies of scale for the BOP.

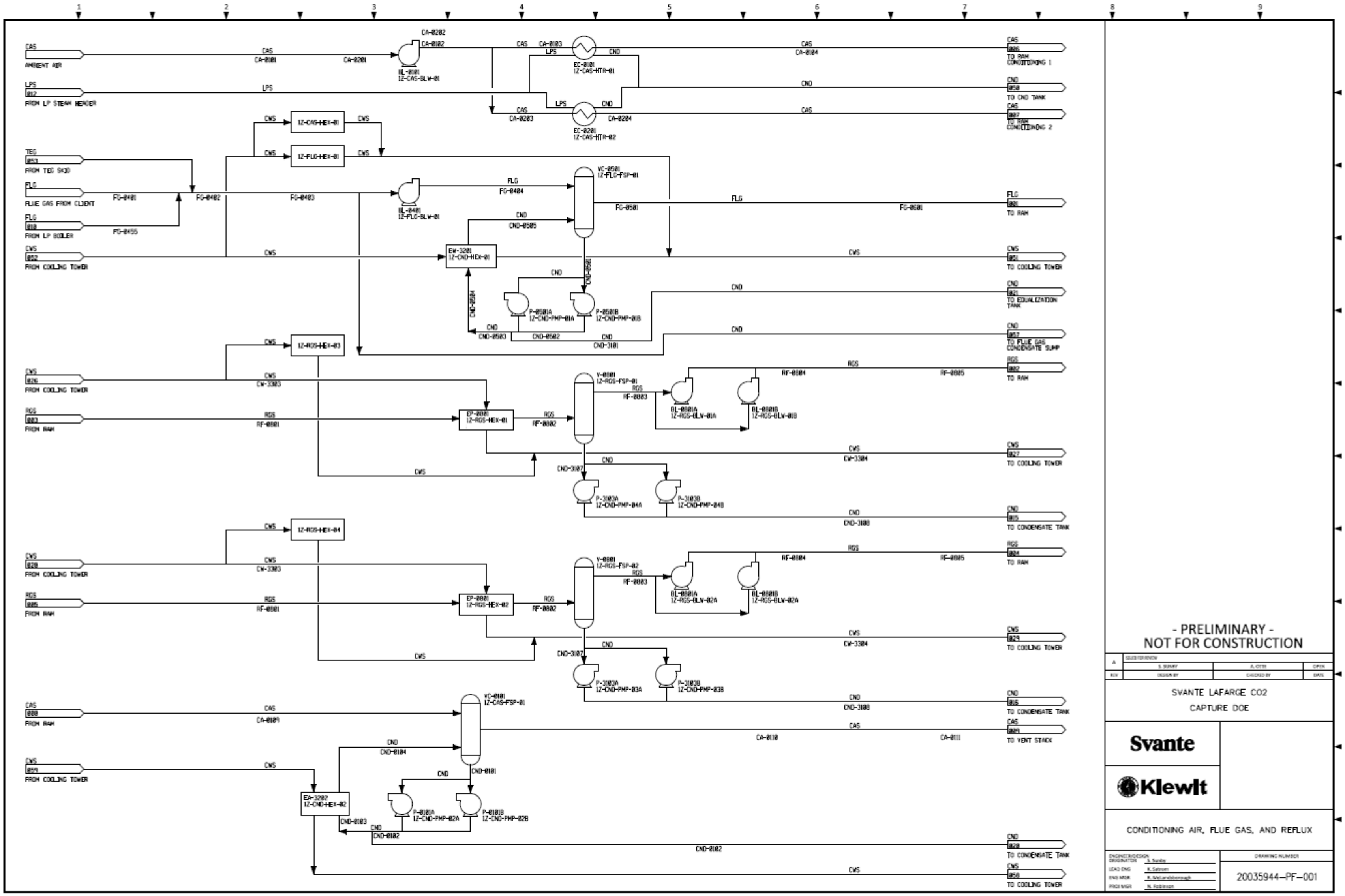


Figure 15 - PFD: Conditioning air, Flue Gas and Reflux

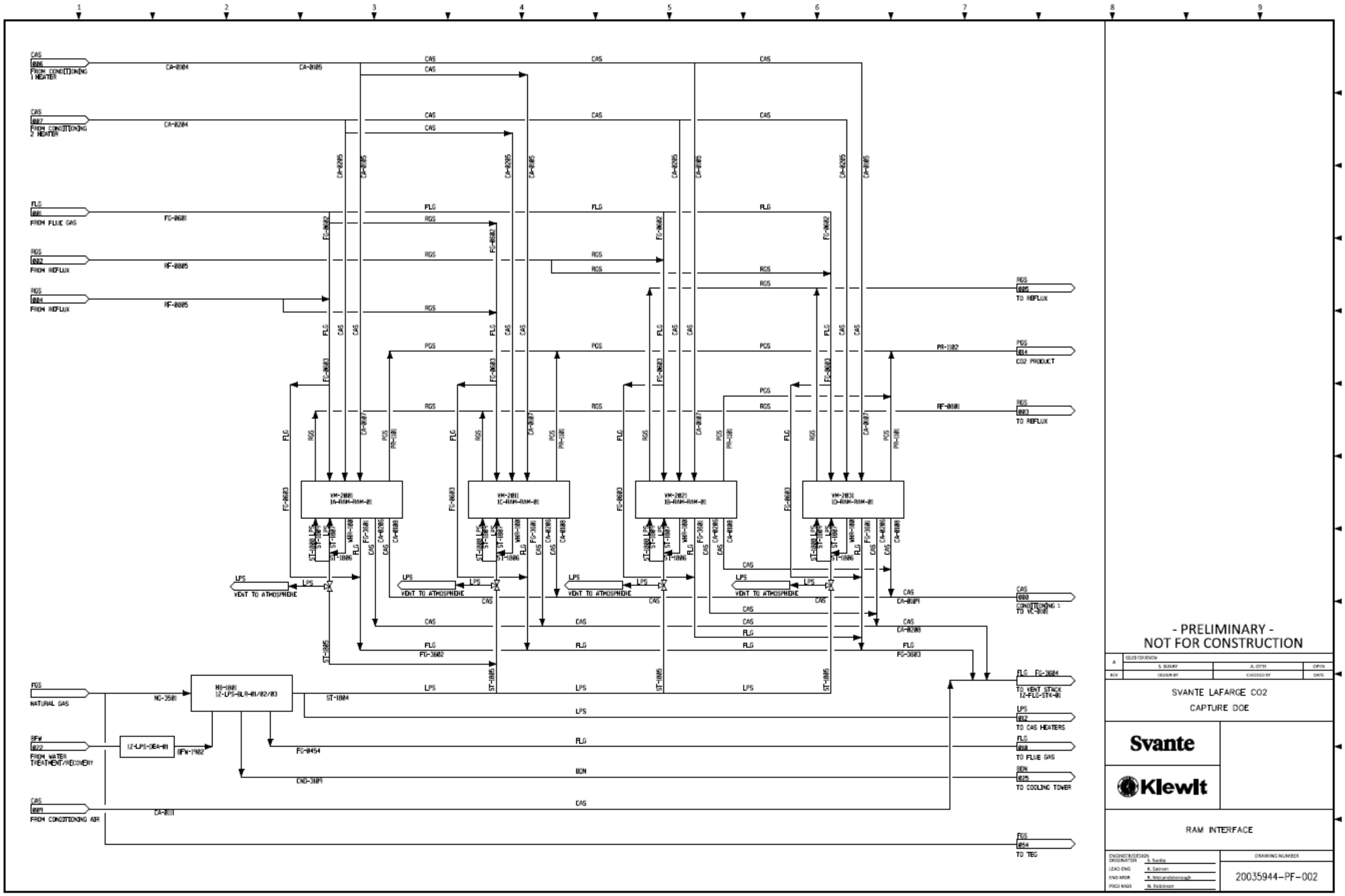


Figure 16 - PFD: RAM Interface

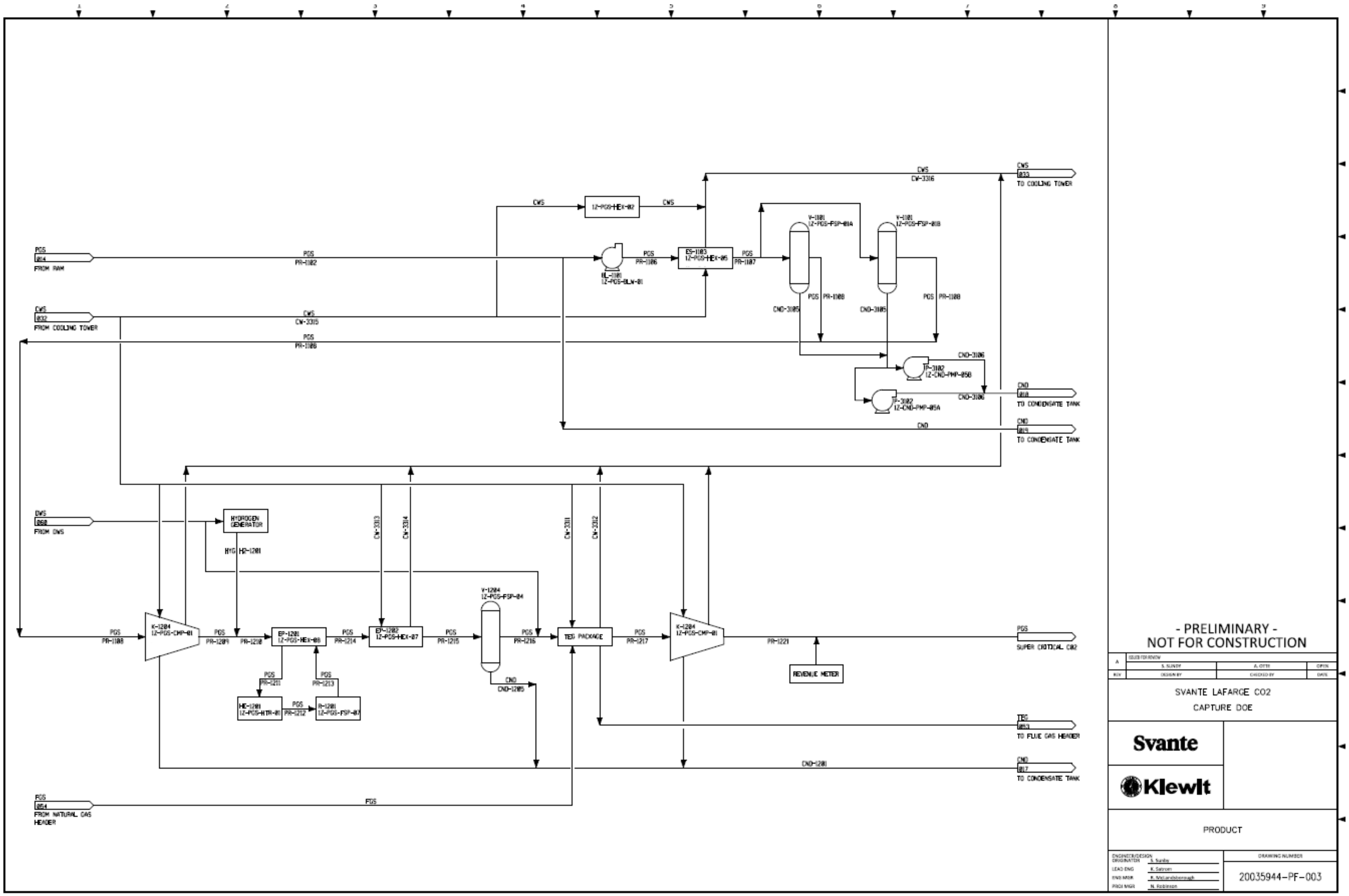


Figure 17 - PFD: Product Gas

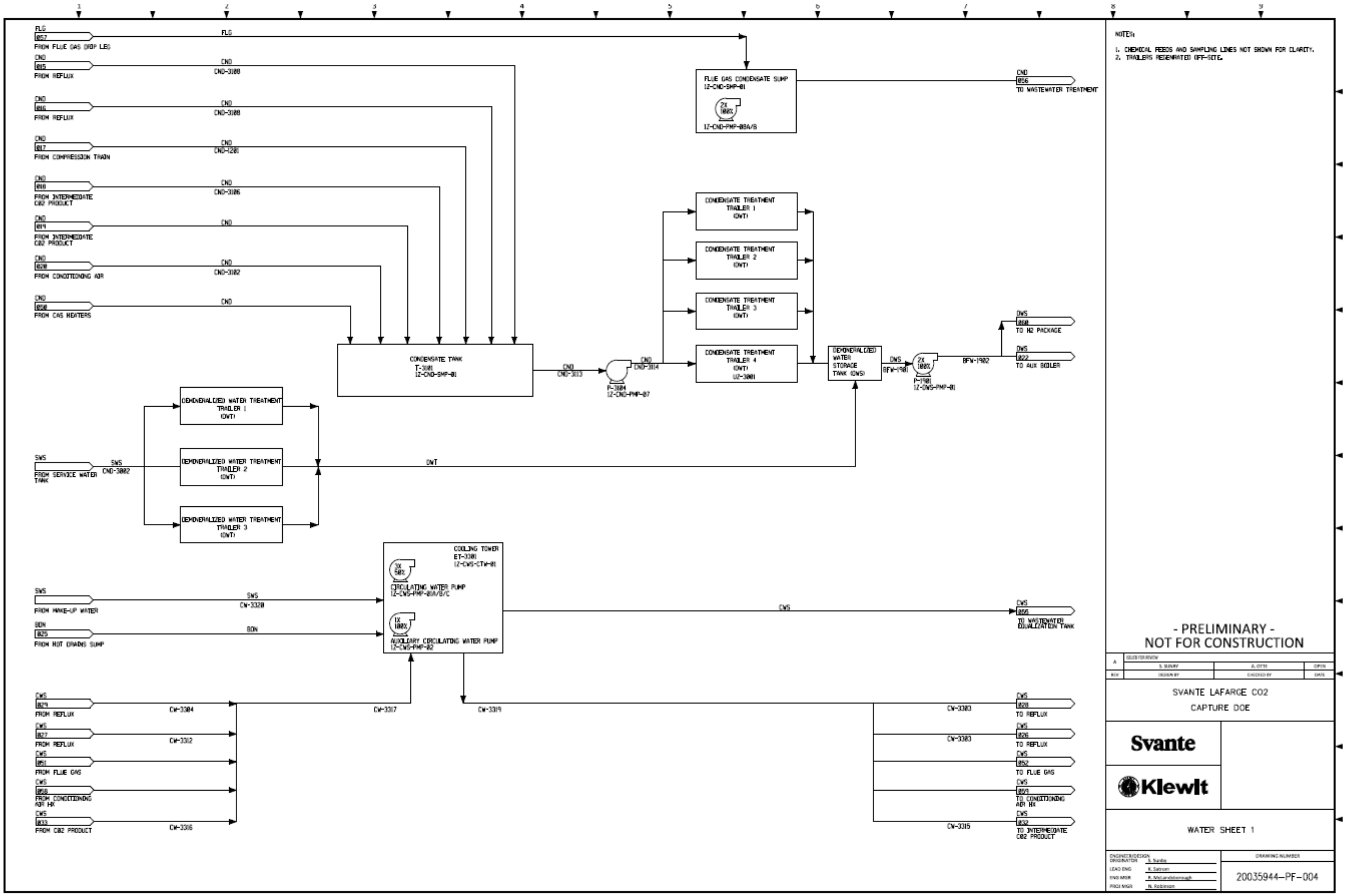


Figure 18 - PFD: Water System, Sheet 1

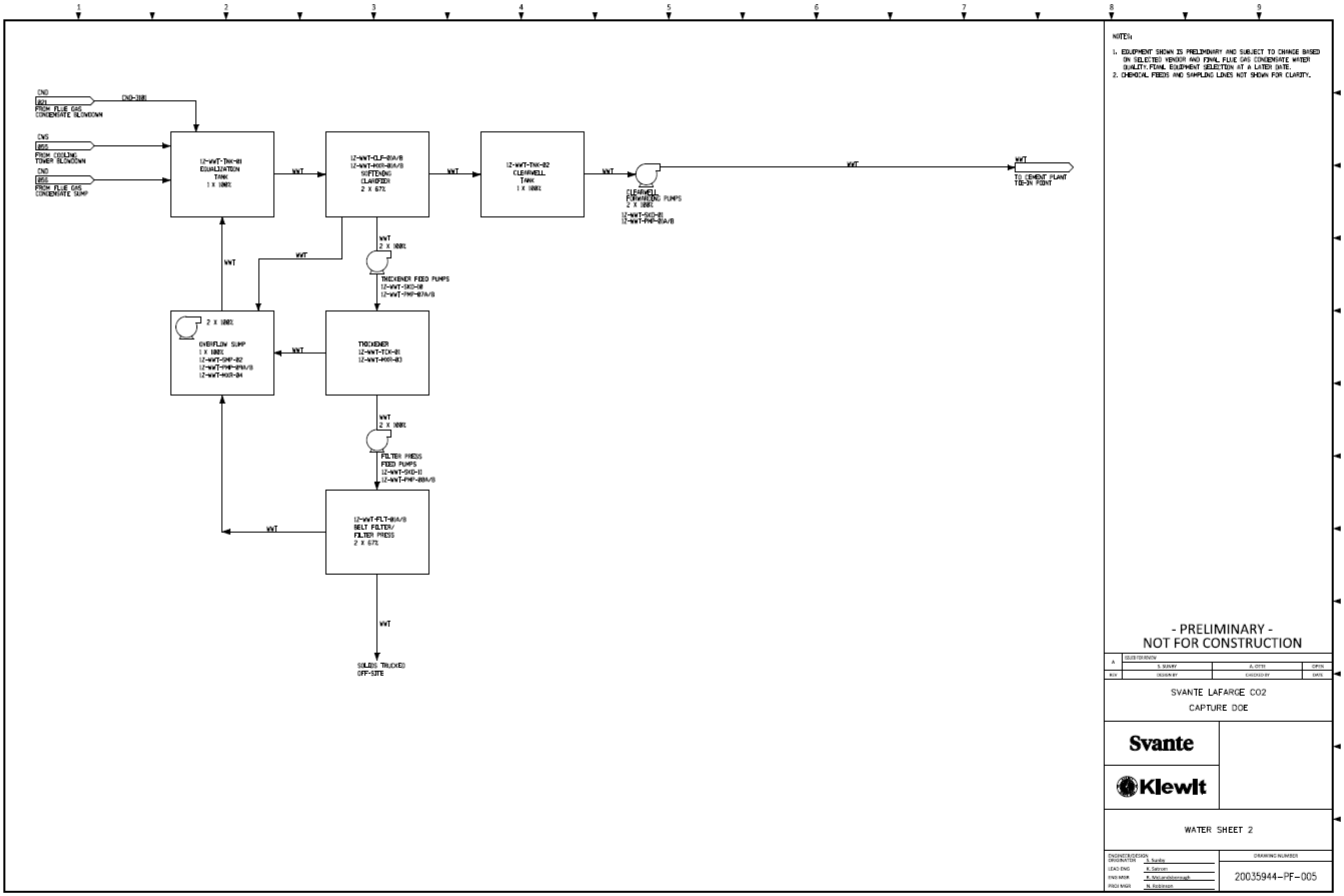


Figure 19 - PFD: Water System, Sheet 2

Figure 20 shows the tie-in points on site map.

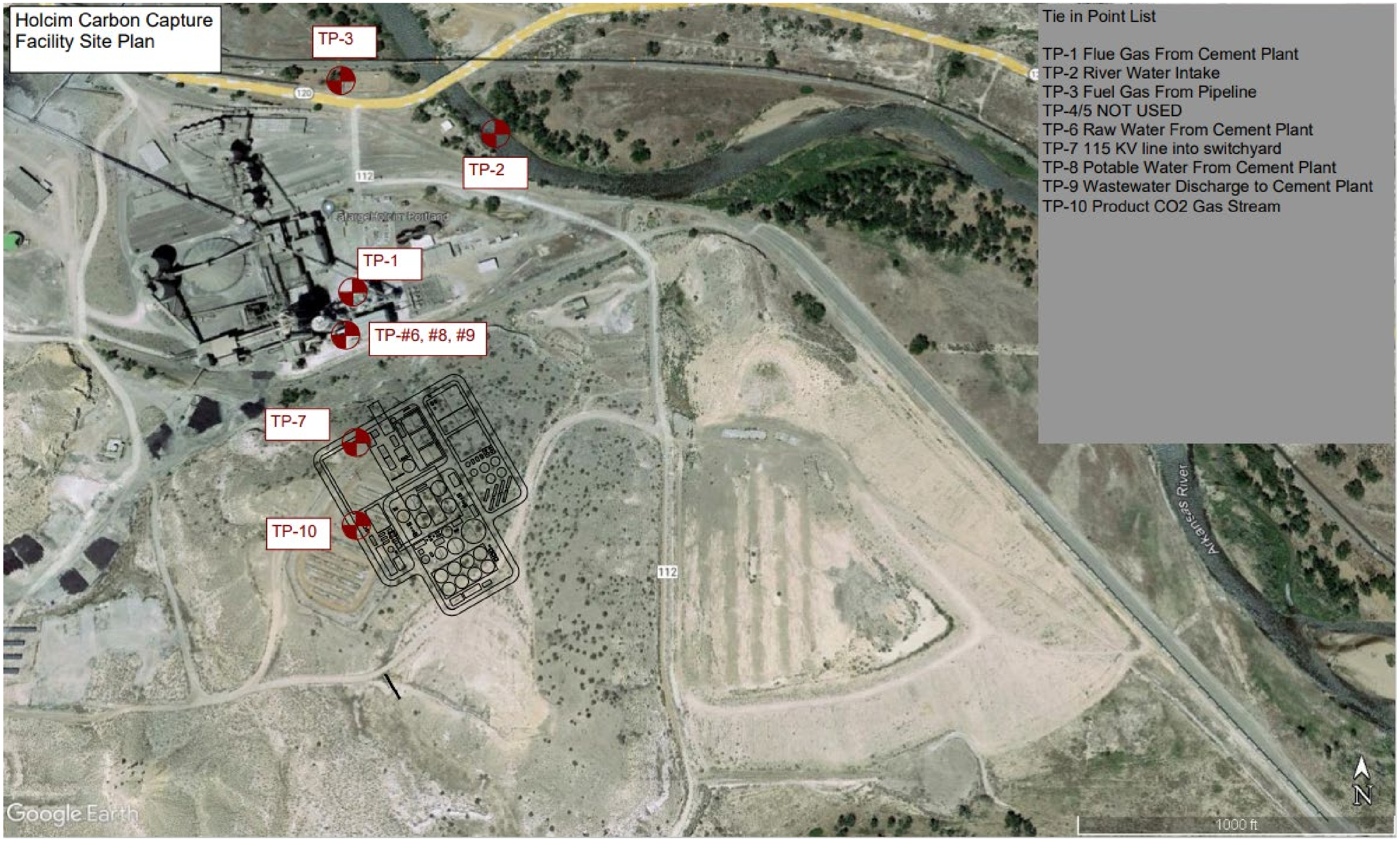


Figure 20 - Site Plan with Tie in Points

Process Equipment

The carbon capture plant adjacent to the HOLCIM cement plant near Florence, Colorado, will be designed to support the Svante VeloxoTherm™ post-combustion carbon capture technology. The carbon capture plant will be controlled independently from the HOLCIM cement plant, but there will be sufficient sharing of operational conditions to ensure safe start-up, operation, and shutdown, as well as allowing for upset investigation and evaluation.

As described in the major equipment list included in Appendix E-2, the following systems will support the CO_2 capture process:

- Flue gas venting and pre-treatment systems
- Conditioning air systems
- Reflux gas system
- CO_2 purification, dehydration and compression systems
- Low pressure steam generation system
- RAM carbon capture systems

Flue Gas

Flue gases from the HOLCIM cement plant, the Triethylene Glycol Regeneration Skid 1Z-TEG-SKD-01, and the steam generators 1Z-LPS-BLR-01/02/03 are pressurized using blower 1Z-FLG-BLW-01 to provide sufficient static pressure to overcome the pressure drop associated with downstream balance of plant equipment and the adsorbent bed before being vented to the stack. The blower is composed of a high-efficiency axial fan with variable pitch blades for flow control.

Flue gas cooling is carried out in a Direct Contact Cooler (DCC). Flue gas enters DCC 1Z-FLG-FSP-01, which provides the cooling required to reach the optimal temperature for CO_2 adsorption. The DCC is designed to cool flue gases to ~40°C. The flue gas flows upwards through a vertical packed bed column where it is contacted with re-circulating process water flowing in a counter-current arrangement. Due to the large interfacial surface area associated with packing, gas cooling is maximized while moisture carryover is decreased.

The circulating DCC water is driven by the DCC condensate pumps 1Z-CND-PMP-01A/B and it is introduced to the top of the packed bed through a liquid distribution system which avoids splashing or droplet formation whilst achieving even distribution to all areas of the packing, forming a thin film of water over the packing surface. The packing, used as the contacting medium, provides the necessary heat transfer area for gas cooling and sufficient mass transfer area for water vapor condensation. A wire mesh type demister installed on the top of the column allows entrained droplet removal from the cooled flue gas.

The DCC water system is a closed-loop configuration with heat exchanger 1Z-CND-HEX-01 which provides the required heat rejection to the Circulating Water system. Cooling of the flue gas condenses a large portion of the water vapor present in the flue gas, therefore the condensate must be removed to prevent accumulation. This excess water is discharged downstream of pump 1Z-CND-PMP-01A/B to the Wastewater Treatment system.

Conditioning 1

Ambient air is pressurized using blower 1Z-CAS-BLW-01 which provides the required static pressure to overcome the pressure drop associated with the adsorbent and downstream balance of plant equipment. This blower is a variable pitch axial fan to control flow. The Conditioning 1 stream is then heated to ~105°C by the steam-heated conditioning heater 1Z-CAS-HTR-01 before being sent to the RAM.

In the FEL-1 phase, a Dowtherm HT Oil was initially considered as a heating medium for the conditioning air. After the FEL-2 analysis, this system was removed from the project. The oil itself is an environmental concern. The oil heating system would contain a considerable amount of equipment which entails installing hundreds of feet of pipe, extending the area of hazardous and environmental concerns. Since natural gas availability will not be an issue, the project team pivoted to heating the conditioning air streams using indirect steam process heaters.

The relative humidity (RH) leaving the Conditioning 1 step is initially high and then reduces as the beds are dried. The Waste Heat Recycle process will take advantage of this by splitting the Conditioning 1 into two outlet ducts (cuts) from the RAM.

In order to reduce the overall make-up water requirement, the second Conditioning 1 outlet stream, which is saturated with water, is then cooled by DCC 1Z-CAS-FSP-01 to ~45°C. The circulating DCC water system is a closed-loop direct cooling configuration with Conditioning 1 DCC condensate heat exchanger, providing the required heat rejection to the Circulating Water system.

This excess water is discharged downstream of pumps 1Z-CND-PMP-02A/B to the condensate collection system. Cooling of the Conditioning 1 outlet is a key step of the plant water management. The cooled Conditioning 1 outlet stream is then vented to the stack.

Conditioning 2

In FEL-1, the system design included two (2) conditioning air blowers, one for each separate conditioning air stream. Through the FEL-2 process, the conditioning air blowers were combined into one (1) common blower for both conditioning streams. The flow will be split going to the heaters so the process can meet the separate temperature requirements for each of the two streams. Buying this larger equipment enables lower capital cost, reduced footprint, lower power consumption, and shortens field work.

Ambient air is pressurized using the same blower serving as motive force for the Conditioning 1 stream, 1Z-CAS-BLW-01. The Conditioning 2 stream is then heated to ~80°C by the steam-heated conditioning heater 1Z-CAS-HTR-02 before being directed to the RAM.

Downstream of the RAM, the Conditioning 2 outlet stream is vented to the stack.

Reflux

Some of the CO_2 released from the adsorbent during the steam push is used by the reflux system to allow for higher purity CO_2 to be produced by the RAM. In FEL-1 each RAM had a dedicated set of reflux equipment. Through the FEL-2 process, reflux equipment was combined into one (1) set of Reflux equipment for two (2) RAMs. Buying this larger equipment enables lower capital cost, reduced footprint, lower power consumption, and shortens field work. The reflux stream exiting the RAM is under slight vacuum conditions and needs to be cooled and pressurized prior to being combined with the flue gas inlet stream to the RAM. Streams coming from two (2) RAMs are combined before they are cooled in plate and frame exchangers 1Z-RGS-HEX-01/02. Moisture is then removed in separators 1Z-RGS-FSP-01/02. Finally, the streams are pressurized using high efficiency turbo fan blowers 1Z-RGS-BLW-01A/B and 1Z-RGS-BLW-02A/B.

CO_2 Conditioning

The hot CO_2 product stream leaving the RAM under vacuum goes through heat exchanger 1Z-PGS-HEX-05 where heat is transferred to the Circulating Water system and the stream is cooled to 35°C before moisture is removed in parallel separators 1Z-PGS-FSP-01A/B. In the FEL-1 phase two (2) cooling stages were assumed, but one (1) was chosen during FEL-2 phase to lower capital cost, reduced footprint, and shorten field work. Product blower 1Z-CAS-BLW-01 is used to control the pressure leaving the RAM.

Initial CO_2 Compression

The cooled CO_2 product under slight vacuum conditions is compressed using a multiple stage compression system. The initial compression to 550 psig is done in five (5) stages. The compressor has an integral cooler after stages two (2) and four (4) for cooling and water removal. The inter-stage cooling is achieved using cooling water and removed moisture is returned to the condensate collection system.

Oxygen Removal

To meet pipeline specifications, the O_2 content in the product CO_2 is reduced from 5000ppm to 10ppm using a hydrogenation process. H_2 is produced in the hydrogen generation skid by the electrolysis of de-ionized water and it is compressed to at least 550 psig prior to being mixed with CO_2.

The pressurized H_2 is then mixed with the compressed CO_2 product and the combined stream is heated to 80°C in heat exchanger 1Z-PGS-HEX-08 before being further heated to 90°C in electric heater 1Z-PGS-HTR-01. The mixture is then sent to the Alumina base Pt impregnated (~ 0.5%) catalytic reactor 1Z-PGS-FSP-07 where H_2 and O_2 react to produce H_2O. The H_2 flow is adjusted based on O_2 composition of the CO_2 product. The outlet stream is cooled down to ~70°C in heat exchanger 1Z-PGS-HEX-08 and then further cooled to 30°C in a trim cooler plate and frame exchanger 1Z-PGS-HEX-07. Moisture is removed in separator 1Z-PGS-FSP-04 and returned to the condensate collection system.

During FEL-2, different methods of oxygen separation were evaluated, notably hydrogenation with electrolysis or distillation. As a result of these efforts, the selected path forward is electrolysis. Following discussions with distillation tower suppliers, it was determined unlikely that there would be sufficient density and velocity differences to ensure adequate separation using distillation.

CO_2 Dehydration

The CO_2 product stream is then sent to a Tri-Ethylene Glycol (TEG) dehydration unit where water is removed to achieve maximum 30lbs H_2O/MMSCF, as per product specification. The CO_2 is contacted with the lean TEG (purity>98.5% w/w) in a packed column 1Z-TEG-TWR-01. Dry CO_2 is then sent to the final compression stages. The rich TEG is regenerated in skid 1Z-TED-SKD-01.

Final CO_2 Compression

The purified and dehydrated CO_2 product is finally compressed to supercritical conditions for pipeline transportation using the final three (3) stages of the multiple stage compression system. The compressor has a final integral cooler after stage seven (7) for cooling and water removal. The inter-stage cooling is achieved using cooling water and removed moisture is returned to the condensate collection system. The final product condition is 15,289 kpag (2,217 psig) at 48°C (118°F).

Circulating Water System

During both FEL-1 and FEL-2, the team investigated 100% dry cooling for the plant, but approach temperature to dry bulb conditions and the resultant cooling fluid temperature at this geographic location were inadequate for the requirements of the process. Wet cooling can reduce footprint, auxiliary power and capital expenses compared to dry cooling. Conversely, a reduction in the cooling tower size would reduce the overall plant water demands but would require the addition of electricity-consuming air-cooled heat exchangers.

Some amount of wet cooling is necessary for Svante's RAM cooling requirements and for other BOP equipment requirements based on maximum allowable water temperatures. FEL-2 evaluations led the design to utilize a cooling tower to obtain the most effective use of capital expenses, operating expenses, and significant footprint and field work reductions. The cooling tower will use the majority of the make up water required for the carbon capture plant. The FEL-2 approach reveals significant benefits when process design excludes all large air-cooled heat exchanger (ACHE) equipment. These benefits will be further validated in the FEED stage using actual cooling tower OEM design data specific to the HOLCIM cement plant.

The circulating water system is a wet cooling tower where water comes in direct contact with upward airflow. This system includes a cooling tower, a basin that collects cold water and a pump which transfers cold circulating water to the users. The tower is filled with structured packing to provide maximum contact between sprayed water and flowing air. The circulating water is cooled to a supply temperature of 28°C in cooling tower 1Z-CWS-CTW-01. Water is then supplied to users via circulating water pumps 1Z-CWS-PMP-01A/B/C. Water make-up is required to compensate for losses due to drift, evaporation, and blowdown. Cooling water return temperature is about 32°C. As the heat exchangers are further evaluated in the FEED stage, the temperature delta across the cooling tower will be refined and validated.

Condensate Collection System

Condensate from the process is collected in the condensate tank 1Z-CND-TNK-01 and sent to the water treatment system via pumps 1Z-CND-PMP-03A/B. The collected condensate requires moderate water treatment to be used as a source of Boiler Feed Water (BFW).

Process Water Treatment

To reduce overall plant make-up water treatment requirements, condensates created at various stages of the process are collected and treated. Condensate from the compression train, product gas separators, and RAM units are collected and treated separately due to their relatively clean quality with respect to the flue gas condensate. This treatment includes weak base anion exchange and mixed bed ion exchange polishing into demineralized water. The weak base anion exchanger was selected to target organics anticipated to be in the compression, product gas, and RAM condensates whereas the following mixed bed ion exchange was selected to remove any remaining total dissolved solids (TDS). Flue gas condensate and cooling tower blowdown streams are blended together in the equalization tank and then treated with a softening clarifier. The softening clarifier was selected to remove total suspended solids (TSS) and the trace metals believed to be carried over in the flue gas condensate. Softening clarifier overflow is then forwarded back for utilization in the cement plant. Solids removed from the clarifier underflow are further treated via a thickener and filter press. Any filtrate is collected and recycled back to the softening clarifiers. Dewatered filter press cake is trucked off-site for disposal.

The path to this water treatment setup during FEL-2 involved many iterations. FEL-2 evaluated zero liquid discharge (ZLD) systems that included seawater reverse osmosis and crystallizer equipment. This ZLD arrangement did significantly reduce off-site disposal costs of wastewater, but the immense capital cost led the team to look for better solutions.

Realizing that the DCC effluent carries constituents from the flue gas that were originally acceptable to have in the flue gas stream, the FEL-2 team investigated returning treated wastewater to the HOLCIM cement plant for use in back-end scrubber processes. Trading that wastewater stream for HOLCIM's raw water allows the carbon capture plant to reduce water usage operational expenses and wastewater disposal. It also significantly reduces capital expenses for water treatment equipment and reduces operational expenses of water treatment equipment.

This path forward has been discussed with HOLCIM and the Svante/Kiewit team, and will be further investigated in the FEED stage, where key metrics like salt ratios and scrubber water quality limits will be evaluated. Coupling this evaluation with river water quality and more precise cooling tower basin cycling, an accurate water quality can be gleaned, and this symbiotic cost-saving approach can be pursued.

Raw Water Treatment

FEL-2 identified the raw water source as river water from the Arkansas River. This source is not as pure as well water or water supplied by tanker trucks. However, it allows for wet cooling as well as any required makeup to generate demineralized water. Biological inhibition and solids removal are required to treat the raw water to service water quality. This will be done using basic filtration and sodium hypochlorite dosing. The basis of this addition is predicated on many past river water treatment applications and will be validated in the FEED stage with actual source water data analysis.

Low Pressure Steam Generation

Treated water is sent to a deaerator as part of the boiler package to remove dissolved oxygen prior to being sent to the boiler. Low pressure steam is provided by natural gas boilers 1Z-LPS-BLR-01/02/03. The flue gas emitted by these boilers is combined with the inlet flue gas stream from the clinker.

FEL-1 presented two (2) BOP arrangement options, including one (1) or two (2) packaged boilers. Collaboration with boiler vendors during FEL-2 further refined and optimized the boiler arrangement and design. FEL-2 sizing demonstrated that up to eight (8) boilers would be required if fire tube type boilers were used. This would represent a much higher maintenance, footprint, and capital cost than using fewer water tube boilers. Water tube boilers do not operate at low pressures like fire tube boilers, however only three (3) water tube boilers are required. The FEL-2 path forward is to use three (3) water tube boilers operating around 100 psig and 338°F to service the entire demand of the four (4) RAMs, which represents approximately 605,246 kg/hr of low-pressure steam.

The Fuel Gas System (FGS) will provide natural gas with an energy level of approximately 1030 Btu/ft^3 (HHV) as the source of fuel for each boiler. The boiler produces saturated steam which is then routed through the Boiler Isolation Valve and Low-Pressure Steam Flow Element to a common header.

The Low-Pressure Steam Header branches off to each of the RAMs. Drip legs are provided at the low points on the Low-Pressure Steam Header to collect any condensate in the piping. Drip legs are provided with manual and automatic drain valves to discharge condensate. Condensate is collected and sent to the Condensate System (CND) for treatment. Boiler blowdown is sent to the cooling tower basin.

In the FEED stage, steam losses as well as accurate ammonia dosage into boiler feedwater for pH control will be identified and documented.

Subtask 3.3 – Outside Battery Limit (OSBL)

Site Planning and Criteria

Site planning will consider terrain, drainage, and land use optimization. The area for the new carbon capture plant will cover approximately 700 ft x 575 ft. This is a meaningful reduction from the FEL-1 area, which fluctuated between a 1000 ft x 800 ft flat pad site and an area of 920 ft x 650 ft. During the FEL-2 process, the team was able to achieve this significant reduction by optimizing plant equipment layout, reviewing redundancies, and most importantly shifting from dry cooling to wet cooling. Once plant water supply from the river was identified, a cooling tower replaced all air-cooled heat exchangers (ACHEs), resulting in a 60% reduction in cooling equipment footprint. The civil cut and fill volume was drastically reduced from roughly 350,000 cubic yards to 150,000 cubic yards, as detailed below.

This site is across the railroad (RR) tracks and roughly 1,000 feet from the tie-in point. The ducting for the flue gas will be bridged over and located about 100 feet above the tracks as shown in Figure 21.

The site has good access via roads to the east and north sides. Some upgrades to the roads may be required for heavy trucks and cranes. Improvement to the roads to the northeast and northwest of the carbon capture plant will be further evaluated in FEED studies as equipment weights, loading, grading, heavy haul routes, and material transport considerations are developed.

The make-up water and natural gas lines will need to pass under the RR tracks. This can be done without taking the tracks out of service by horizontal drilling.

Ducting for the communication cables to the HOLCIM cement plant will be placed on the new bridge described above. This will include any fiberoptics or hardwire control systems.

The original site evaluation provided two (2) possible locations detailed in the previous Owner’s report. The site in red border shown below in Figure 21. was selected and used in FEL-2 as the best location due to the shortest distance for the flue gas ducting connection to the carbon capture plant. The orientation of the site has been adjusted to accommodate the power lines and roads required for access (ref Figures 21, 22 and 23).

Figure 21 - Carbon Capture Plant Location

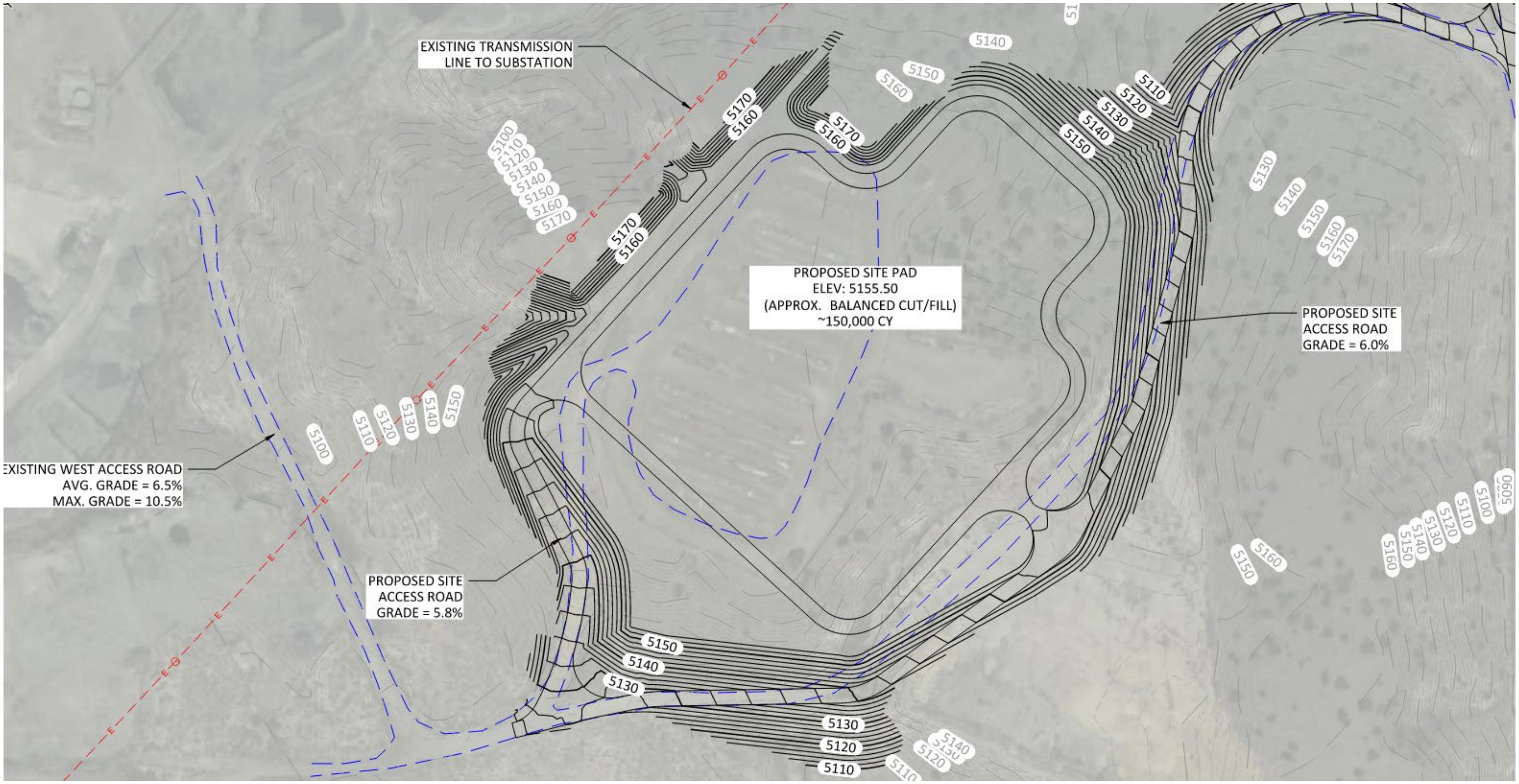
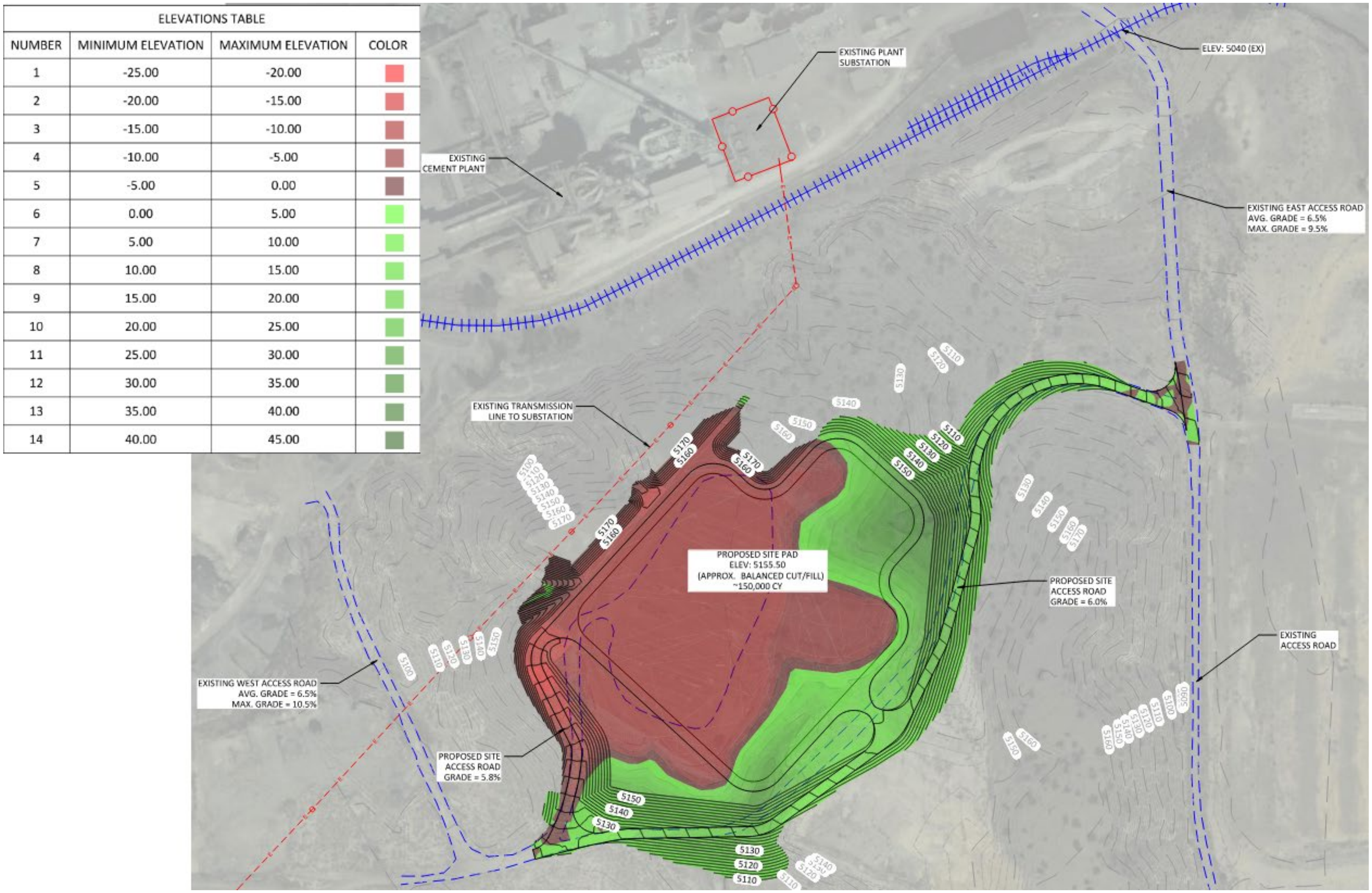


Figure 22 - Preliminary Site Grading for Carbon Capture Plant



ELEVATIONS TABLE

NUMBER	MINIMUM ELEVATION	MAXIMUM ELEVATION	COLOR
1	-25.00	-20.00	
2	-20.00	-15.00	
3	-15.00	-10.00	
4	-10.00	-5.00	
5	-5.00	0.00	
6	0.00	5.00	
7	5.00	10.00	
8	10.00	15.00	
9	15.00	20.00	
10	20.00	25.00	
11	25.00	30.00	
12	30.00	35.00	
13	35.00	40.00	
14	40.00	45.00	

Figure 23 - Preliminary Site Grading, Cut and Fill Heat Map

Geotechnical and Site Drainage

The FEL-1 preliminary civil layout and grading plan for the LH CO_2MENT COLORADO project was based on providing a 1000 ft x 800 ft flat pad site for the proposed carbon capture plant, an area which was further optimized, and the size reduced during FEL-2, as stated above.

The existing terrain is highly variable in elevation with the railroad track crossing adjacent to the HOLCIM cement plant at elevation (EL) 5040, and the new pad site at +/- EL 5155. The pad is situated parallel to the existing overhead transmission line feeding the cement plant and set-back far enough to avoid being impacted by the existing vertical rock bluffs.

The pad is set at EL 5155 to create a balanced site with approximately 150,000 CY of cut and 150,000 CY of fill. Cut and fill slopes are shown at 2H:1V (ref Figures 22 and 23), based on the rocky nature of the site. No geotechnical study has been performed on the site. If slopes flatter than 2H:1V are required due to soil stability concerns, retaining walls will likely need to be utilized in some areas. Existing rock bluffs are visible at EL 5125 but it is unknown, without geotechnical soil borings, if bedrock will be encountered in areas where ground will be cut from EL 5170 down to the pad site at EL 5155, or lower for foundations.

The access road in from the east side will require to be graded to 5% or less, for heavy haul and construction traffic. The primary permanent entrance route will be located approaching from the west. The existing western access road would need to be widened and re-graded to a maximum of 6% gradient from existing EL 5075, up to the pad at EL 5155.

If stormwater controls are required, a retention basin should be located south of the pad site within the drainage draw that flows south-easterly. The FEED will investigate this stormwater control approach in greater detail.

A geotechnical assessment will be conducted during the FEED phase. Currently, engineers have assumed 1500 lb/ft2 for the soil load bearing capacity. The site will be graded and the scraped material will be used to fill in the lower areas, resulting in a dirt neutral site plan. The recovered fill material will be compacted to support equipment and buildings. If necessary, the disturbed areas may require some piles in order to support heavier loads, as will be determined in a future FEED study.

The drainage from the site will be collected and either sent to a retention pond before release or tied into the existing drainage system and retention pond. Final determination will require an engineered drainage plan.

Site Infrastructures

The HOLCIM cement plant is located off Highway 120, which is an all-weather road. Heavy equipment and supplies can be transported along this road. There is a bridge over the Arkansas River that is rated for heavy trucks and will suffice for any equipment transportation required for the project. State Road 112 is available but rarely used. In the current plan, Road 112 will not be used for construction nor access to site. During the winter, Highway 120 is maintained as an emergency route for the city of Florence, Colorado. Highway 120 connects to Highway 50 and this highway connects to Pueblo Colorado to the east. Pueblo has business space, hospitals, and retail for any project necessities.

The site is located near all required utilities. The orange box in Figure 24 indicates the area where the water will be sourced from the Arkansas River, which is owned by the Pueblo Water District. A natural gas pipeline is located north of the HOLCIM cement plant as identified by the blue box in Figure 24. The green box indicates the planned natural gas expansion location. Power comes from a high-power transmission line which presently supplies the HOLCIM cement plant. These power lines will need to be either replaced or new conductors added to supply the carbon capture plant with power. The existing power lines were sized for the HOLCIM cement plant in 1996.

The wastewater and internet services are not currently supplied at the carbon capture plant site. These will be detailed in the FEED study.

Figure 24 - Carbon Capture Plant Site Utilities Location (Natural Gas and Water)

Subtask 3.4 – General Arrangements

Much of the information to answer this Subtask was covered in Subtasks 3.1. 3.2 and 3.3 above. The general arrangement drawing and process modeling contributed to the accuracy of the construction cost and material cost.

Preferred Site Configuration

The location of the carbon capture plant site is at closest proximity to the HOLCIM cement plant flue gas stack but with a long distance of flue gas ducting, i.e., approximately 454 m or 1,000 ft. A railway and low-lying area are located between the carbon capture plant site and the flue gas stack. This gap will need to be bridged for ducting, piping and communications. There was no other site location with a better proximity.

During FEL-2, various configurations of the BOP equipment were considered, and specific high value areas were targeted for Value Engineering efforts to streamline the design, equipment layout and total installation cost. The Plot Plan is in Appendix D. This work resulted in optimized plant layout, reduced piping and electrical quantities, reduced steel quantities, improved trailer and operations access, reduction in ACHE sizing, and optimized administration and warehouse facilities. It is expected that additional optimizations will be identified and incorporated in the FEED stage of the project.

Feed Gas Stream Composition

The feed stream from the HOLCIM cement plant will vary based on the various fuel blends and the raw materials in the kiln. In November 2020, Svante undertook the analysis of the 2017-2020 hourly plant data for the HOLCIM cement plant stack and clinker cooler air process parameters, as illustrated in Figure 25. The objective of this analysis was to estimate the flue gas conditions after the wet scrubber (TP-1 – Flue gas WS stream) from the available historical plant data in order to establish the boundary operating limits described in Table 6.

Table 6 - HOLCIM Cement Plant Capacity

Client Facility	Unit	Low End	High End
Clinker Production Rate	TPD	4,600	5,200
	TPH	192	216
	TPA @ 85% OEE	1,430,000	1,610,000
CO_2 Ratio	kgCO_2/ton Clinker	700-800	700-800
Stack Flow Rate	am^3/h	1,150,130	1,195,050
Kiln Flow Rate	am^3/h	700,130	745,050
Temperature	°C	69	70
H_2O	%v/v	14	14

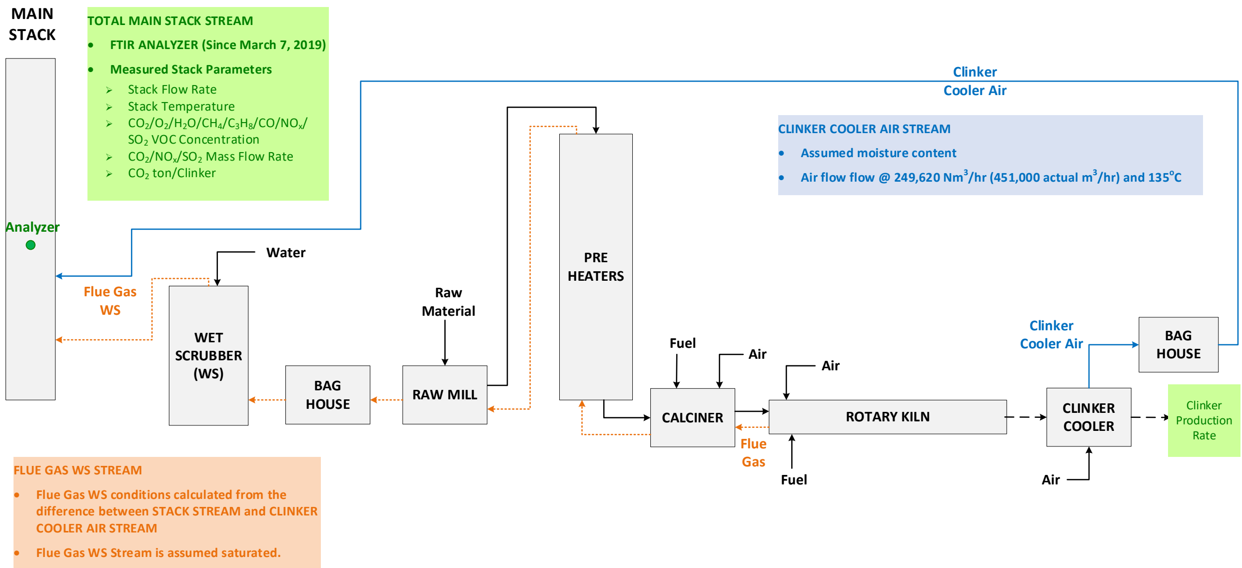


Figure 25 - HOLCIM Cement Block Diagram

Subtask 3.5 – CO_2 Storage –Assessment of High-Grade Prospects

Subtask 3.5.1 – Saline Aquifer Storage

Subtask 3.5.2 – Depleted Oil/Gas Field Storage

Subtask 3.5.3 – Storage in Sheep Mountain CO_2 Source Field

Subtask 3.5.4 – CO_2 EOR Storage

Information relative to subtasks 3.5.1, 3.5.2, 3.5.3 and 3.5.4 is presented below.

The carbon capture plant will be sited adjacent to the HOLCIM cement plant, which is located near Florence, Colorado. CO_2 transport will be accomplished by pipeline from the capture site to one of two storage sites that were selected during FEL-2, from the options considered in FEL-1.

The original scope of this study included selecting one of four storage site options evaluated in FEL-1 for refinement in FEL-2. However, the scope was modified to include the further evaluation of two of these initial options; one option that includes utilization of the CO_2 for EOR and the other option which is based on sequestration without utilization. This modification will allow flexibility to choose the best storage option in the detailed engineering phase of this project, when the value of storage credits, incentives and other economic parameters are expected to be more certain.

The HOLCIM cement plant is located within 54 miles of the existing Sheep Mountain Pipeline (SMPL) which provides access to both of the selected storage options for sequestering CO_2. A new section of CO_2 pipeline will be constructed to connect the carbon capture plant to the SMPL.

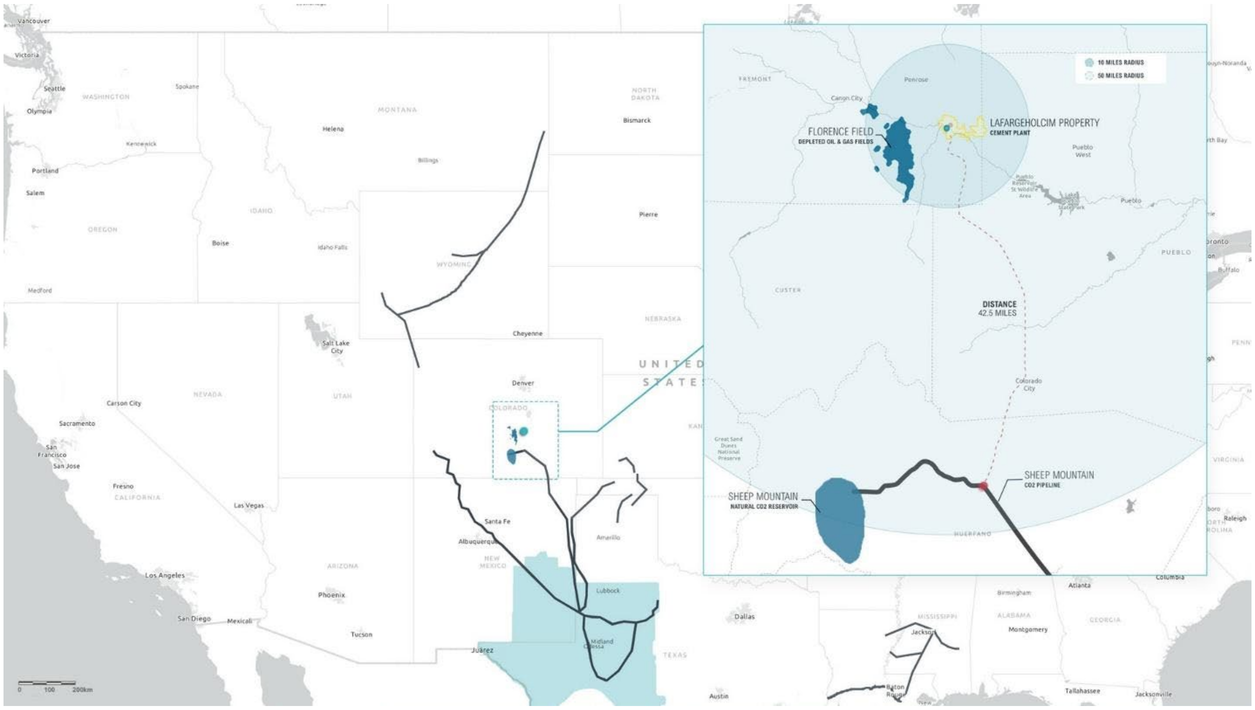


Figure 26 - Map of HOLCIM Cement Plant, Existing Pipelines and CO2 Storage Locations

The captured gaseous state CO_2 will be transformed into a dense phase for more efficient transport, i.e., reduced pipeline size and cost. This dense phase may be a liquid or a super-critical fluid.

For the LH CO_2MENT COLORADO project, both CO_2 storage options selected for consideration involve the secure and permanent geologic sequestration of CO_2 deep beneath the Earth's surface.

The four (4) storage options shown below were evaluated in FEL-1.

- Option A: Storage in a saline aquifer
- Option B: Storage in depleted oil and/or gas fields
- Option C: Storage in the Sheep Mountain CO_2 natural source field
- Option D: Storage using CO_2 EOR in existing fields

Option D, Storage using CO_2 EOR in existing fields, is the only storage option that includes CO_2 utilization. This option is also based on a safe and proven process and was therefore selected for further refinement in FEL-2.

Option B, Storage in depleted oil and/or gas fields, was discarded in FEL-1 due to the absence of depleted oil and/or gas fields within a 50-mile radius of the capture plant.

Valid storage options that do not include utilization are Option A - Storage in a Saline Aquifer; and Option C - Storage in the Sheep Mountain CO_2 natural source field.

Option C, The Sheep Mountain field presents a safe and high degree of confidence for permanent storage due to its proven ability to store CO_2 for millions of years. The sequestration fee estimates from FEL-1 also showed that the Sheep Mountain field had the most economically attractive sequestration fees of the two non-utilization options. It is for these reasons that Sheep Mountain CO_2 natural field was chosen as the second option for further refinement in FEL-2.

Option A, Additional efforts to further explore the potential for local storage in a Saline Aquifer have resulted in this being a potential storage option but shall be evaluated for viability, safety and financial feasibility in the next phase of the project.

Figure 27 shows that both selected storage options include a 'new' pipeline that will transport CO_2 from the carbon capture plant to a tie-in point into the existing CO_2 transportation network. The existing routes, 'SMPL West' and 'SMPL South' will transport CO_2 to either the Sheep Mountain CO_2 source field, or to CO_2-EOR fields via the Denver City CO_2 hub.

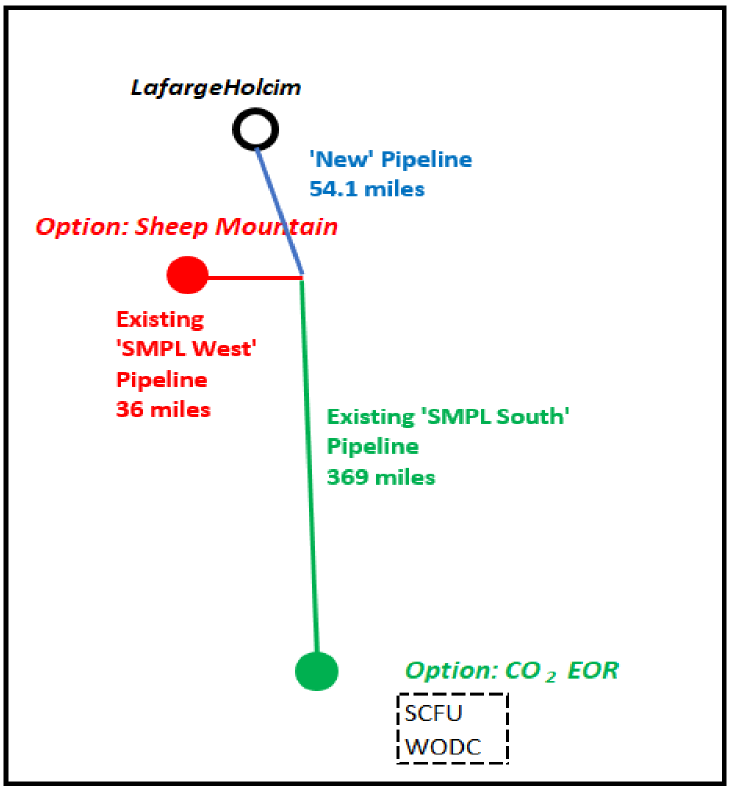


Figure 27 - Depiction of Pipeline Distance and Location for Selected CO2 Sequestration Options

The Sheep Mountain CO_2 source field is a natural geologic trap that has held accumulations of CO_2 for millions of years. It is largely depleted of natural CO_2 and could be converted into a CO_2 sequestration hub that could hold up to 75 million tonnes of anthropogenic CO_2, which is equal to the amount of gas that has been voided from the Sheep Mountain field over its producing stage. The field includes 28 existing wells. The assessment calculates that 11 of the existing wells would be converted to UIC Class VI injection wells to inject the CO_2 captured from the HOLCIM cement plant. Some of the remaining wells would be used for monitoring purposes and the remainder would be permanently sealed.

OLCV identified the Salt Creek Field Unit (SCFU) and the Wasson Old Denver City (WODC) unit as two existing CO_2-EOR projects located in the Permian Basin of West Texas that could receive CO_2 via the Sheep Mountain pipeline and provide a combined total secure geologic storage potential of 2 million tonnes of CO_2 per year for a period of 20 years. This volume is over double the amount of CO_2 expected to be captured from the carbon capture plant. The SCFU and WODC unit are existing projects that are very well characterized geologically and have demonstrated the ability to securely sequester CO_2. No additional UIC permits are required as CO_2 is already being sequestered in these EOR projects using existing UIC Class II injection wells.

CO_2 Transport Safety Considerations

All the options evaluated during FEL-2 include CO_2 transportation by pipeline. The pipeline transport of CO_2 is a well-established engineered method with an excellent safety record. Safety considerations are taken into account during the design, construction and operations of the pipeline system. The pipeline safety design considerations include:

- Pipeline designed per Department of Transport (DOT) regulation 49 CFR Part 195, "Transportation of Hazardous Liquids by Pipeline"
- Pipeline to comply with Federal (USACE, USFWS, EPA) and State of Colorado permitting requirements for design, construction and operation
- Pipeline wall thickness calculated per ASME B31.4 with appropriate design factors. Pumping station piping designed per ASME B31.3. All equipment in the pipeline system designed, fabricated, installed and operated per established industry standards such as ASME, ASTM, ANSI, API, NACE, NEC, NEMA
- Per DOT requirements, facilities to be installed to pig the pipeline once every five (5) years for cleaning and inspection of the pipeline
- Pipeline to be co-laid with fiber optic cable that will serve both communication and leak detection
- Composite sleeve crack arrestors or equal to be installed along the pipeline to prevent crack propagation
- Impressed current cathodic protection system to be installed for corrosion control of buried pipeline segments
- During the operational phase, the pipeline will be continuously monitored by metering both the inlet and outlet from the pipeline that will continuously monitor any volumetric loss from the pipeline. This is in addition to the leak detection system

During the next stage of the project, the following studies will be conducted to determine any risks and to recommend risk mitigation actions:

- HAZOP conducted for the pipeline system and recommendations provided to mitigate identified risks

- High Consequence Area (HCA) analysis and Emergency Flow Restriction Device (EFRD) study conducted to locate potential areas of high impacts due to leaks and the need for shut off valves to prevent threat to surrounding areas.

Sheep Mountain CO_2 Reservoir

A report on the various options of CO_2 transport and storage assessment was completed by OLCV in FEL-1. The Sheep Mountain Unit (SMU) is a natural CO_2 source field located about 20 miles northwest of Walsenburg in Huerfano County, Colorado in the Raton Basin (Ref. Figure 28). SMU is a natural geologic reservoir that has securely held CO_2 for millions of years. The field is situated within the Sangre de Cristo fold and thrust belt and has produced roughly 1.5 trillion standard cubic feet (75 million tonnes) of naturally occurring CO_2. The field has been in production since the 1970s and the reservoir pressure has been depleted to 150 psi from an initial pressure of 1,500 psi. This has resulted in a substantial low-pressure pore volume that could be used to accept injected CO_2 for secure sequestration. The field would be able to sequester an amount of CO_2 equal to or greater than the amount of CO_2 that has been withdrawn.

The field is organized into five pads, or drill sites, from which wells were drilled directionally to specific CO_2 production points in the reservoir. The field is located at the head of the Sheep Mountain CO_2 pipeline that currently transports dense phase CO_2 to a hub located in Denver City, Texas, where it is distributed to various Enhanced Oil Recovery (EOR) projects in the Permian Basin of West Texas.

The Sheep Mountain CO_2 field is located south of the HOLCIM cement plant in south-central Colorado. A 12" ANSI/ASME Class 900 pipeline, 54.1 miles in length, will be routed from the cement plant to a tie-in point on the existing Sheep Mountain Pipeline (SMPL), as shown in Figure 28. From the tie-in point, the CO_2 will be transported through the 'SMPL West', on a distance of 36 miles to the Sheep Mountain CO_2 field for sequestration. The 'SMPL West' is a 20"/24" ANSI/ASME Class 1500 pipeline that currently transports CO_2 from the Sheep Mountain field to the Permian Basin. After the tie-in of CO_2 pipeline from the HOLCIM cement plant, the direction of flow in the 'SMPL West' will be reversed so that the CO_2 will flow from the tie-in point to the Sheep Mountain field for sequestration.

The dry CO_2 captured at the Holcim cement plant will enter the 'new' 12" pipeline at 2,100 psig. The pressure at the end of the 54.1-mile 'new' pipeline, at the tie-in point to the 'SMPL West', will be 1,350 psig. A pressure booster station will be installed at the tie-in point to raise the pressure from 1,350 psig to 1,650 psig to meet the 'SMPL West' pressure requirements prior to entering that pipeline. The CO_2 routed through the 'SMPL West' will reach the Sheep Mountain field for sequestration at 800 psig.

There is an existing surface network of pipelines connecting the Sheep Mountain wells to the Sheep Mountain Pipeline. The infrastructure will have more than enough capacity to geologically sequester CO_2 on the high side case of 2 million tonnes of CO_2 per year for 20 years (40 million tonnes), that may be captured from the LH CO_2MENT COLORADO project.

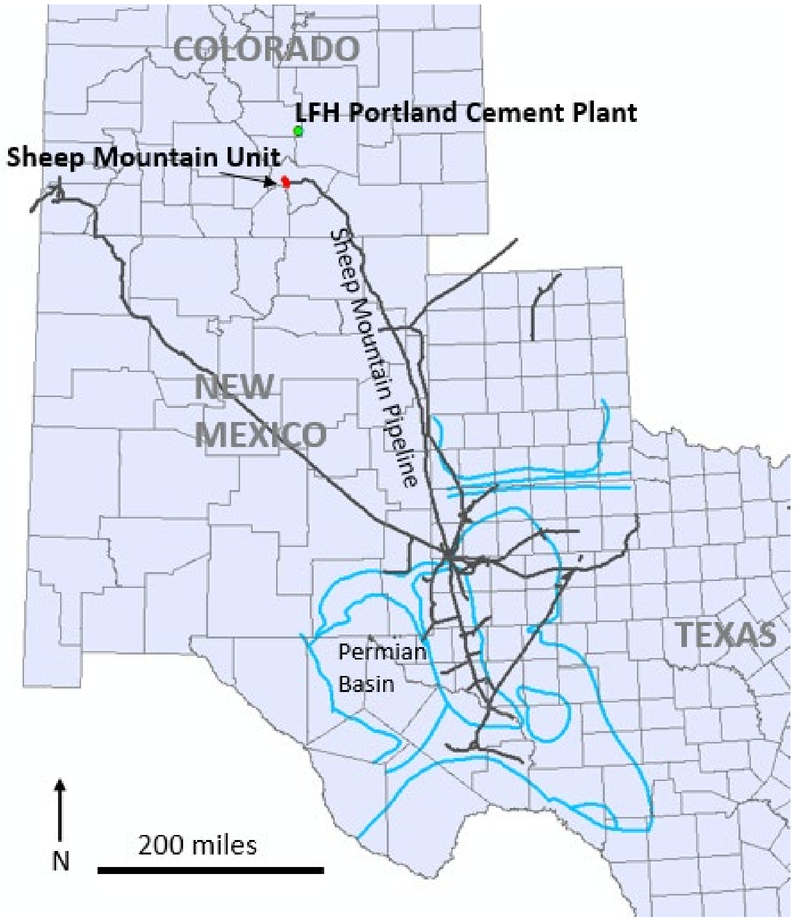


Figure 28 - Location of the Sheep Mountain Unit in south-central Colorado

The Sheep Mountain Unit (SMU) was designed for high-pressure production of CO_2; therefore, the existing wells and infrastructure were constructed with materials and methods compatible with CO_2 exposure. There are 28 active wells at SMU and an additional 3 inactive (temporarily abandoned or plugged and abandoned) wells. Of the active wells, most are suitable to be converted to UIC Class VI CO_2 injection wells. Any wells not used for injection will be utilized for monitoring purposes or will be permanently sealed.

CO_2 EOR

CO_2 EOR is recognized as a safe, practical and lowest cost option for storing the CO_2 captured at the LH CO_2MENT COLORADO project. This option can most quickly be readied for accepting anthropogenic CO_2, needing only an MRV plan put in place. Injection permits and monitoring protocols already exist at both the SCFU and WODC fields.

For transporting the captured CO_2 to the Permian Basin for use in CO_2 EOR, a new 12" ANSI/ASME Class 900 pipeline ('new' pipeline), 54.1 miles in length, will be routed from the HOLCIM cement plant to a tie-in point on the existing Sheep Mountain Pipeline (SMPL), as shown in Figure 29. From the tie-in point, the CO_2 will be transported through the 'SMPL South' pipeline, on a distance of 369 miles to the Denver City hub in the Permian Basin. The 'SMPL South' is a 20" ANSI/ASME Class 1500 pipeline for 144 miles from the tie-in point toward the Permian Basis, and it increases to a 24" diameter for the final 225 miles to the Denver City hub, which is also the location of the Wasson Old Denver City (WODC) unit. From the Denver City hub, the CO_2 may also be transported via the existing 45-mile, 12" Este II pipeline to the Salt Creek Field Unit (SCFU).

Figure 29 - Route of new 54.1 miles pipeline from HOLCIM cement plant to tie-in on the existing SMPL

Out of multiple viable CO_2 EOR options for sequestering CO_2 from the carbon capture plant, OLCV selected SCFU and the WODC unit as the two existing CO_2 EOR projects located in the Permian Basin of West Texas that can provide a combined total secure geologic storage potential of 2 million tonnes of CO_2 per year (104 MMscf/d) for a period of 20 years. The fields are located as shown in Figure 30.

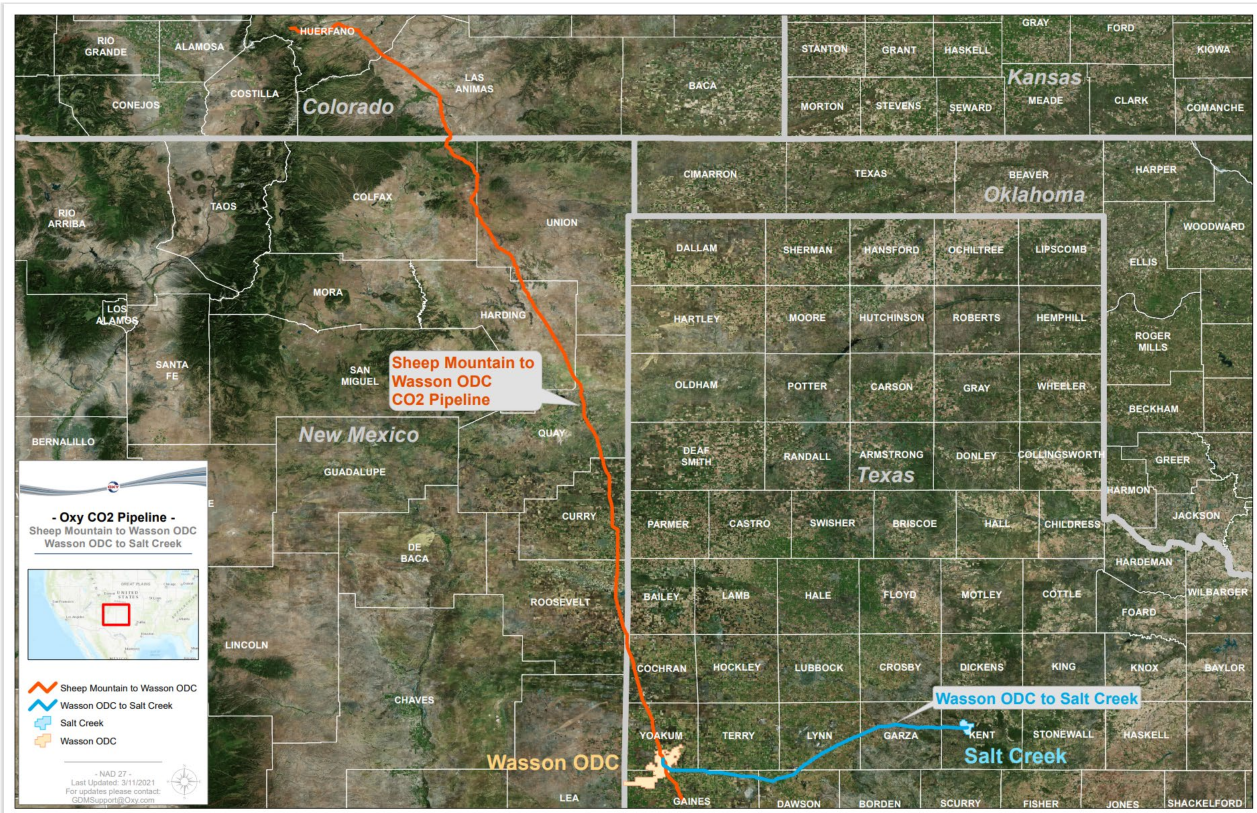


Figure 30 - Location map of Salt Creek Field Unit (SCFU) and Wasson Old Denver City (WODC) Unit, proposed sites for secure geologic storage of CO2

Pipeline Capital Cost

Capital costs for pipeline construction from the FEL-1 work have been revised and updated. The design characteristics of the pipelines are unchanged since CO_2 flowrate and pressure conditions are the same as during completion of the FEL-1 report. Costs for pipeline construction were reviewed and revised as appropriate. The primary updates relate to the costs to construct the 54.1 mile long 'new' pipeline. Since the original FEL-1 estimate, the costs of the materials used for the line pipe, which is 12" diameter with a 0.375" wall thickness and X-65 grade has increased by 40% in U.S. dollars. The labor cost for constructing the pipeline has also increased. This increase is based on actual budgetary estimates and is 10% higher than the FEL-1 estimate. The updated capital cost estimate is $102MM. This was based on the following assumptions:

- Quantities of material are estimates only and pricing of material was obtained from prior projects in the area conditioned with current price quotes;
- A tax rate of 11.2% was used for all procured materials to account for Colorado sales tax and municipality tax.

Storage at CO_2 EOR field

For this option, the only new infrastructure being installed is the 'new' 12" diameter pipeline from the HOLCIM cement plant to the SMPL tie-in point, including the pressure booster station. All other infrastructure, i.e., transport through 'SMPL South' and Este II pipeline, and EOR at the Salt Creek Field

Unit and Wasson Old Denver City fields, are already in place and do not need any modifications. This option would utilize the 'new' pipeline and the 'SMPL South' shown in Figure 27. The cost estimate is a Class IV estimate per AACE with an accuracy of -20%/+30%. The pipeline installation costs would be borne by OLCV and recovered through a pipeline tariff.

Storage at Sheep Mountain CO_2 Natural Source Field

The TIC for the infrastructure described above includes the cost of the 'new' 12" diameter pipeline from the HOLCIM cement plant to the tie-in to the SMPL, changes to the 'SMPL West' pipeline to reverse the flow direction, and surface facilities at the Sheep Mountain field for sequestration of CO_2. This option would utilize the 'new' pipeline and the 'SMPL West' pipeline shown in Figure 27. The cost estimate is a Class IV estimate per AACE with an accuracy of -20%/+30%. The capital costs for CO_2 transportation to the Sheep Mountain field would be borne by OLCV and recovered through pipeline tariffs. The estimated cost of this pipeline option is slightly higher at $104MM.

CO_2 Sequestration Fees

The Sheep Mountain CO_2 sequestration fee ranges from $34.00/MT for the low-side case to $48.00/MT for the high-side case. It includes insurance to protect against any unexpected leakage of CO_2 that would result in the invalidation of CO_2 credits generated by this Carbon Capture Sequestration (CCS) project. Tariffs for the 'new' pipeline and the 'SMPL East' are used to transport CO_2 from the cement plant to the Sheep Mountain CO_2 Storage Field.

The CO_2 EOR sequestration fees estimated in FEL-1 are still valid and were used in FEL-2. This is because the two CO2 EOR projects selected to store the CO2 from the LH CO2MENT COLORADO project are existing projects with well understood costs and sequestration performance parameters. The sequestration fees range from $5/MT to $20/MT depending on market conditions.

For Option A, local storage in a Saline Aquifer, a rough estimate was prepared– to be further evaluated for technical viability and commercial feasibility in the next phase of the project.

CO_2 Pipeline from HOLCIM plant to SMPL Schedule

An anticipated schedule is provided for the potential pipeline connecting the HOLCIM plant to the SMPL in Appendix A-2 for a baseline assessment.

Subtask 3.6 – Environmental Permitting

Environmental permitting will require a considerable amount of work and review with the appropriate agencies. The main agency to coordinate with for this project is the Colorado Department of Public Health and Environment (CDPHE). During FEL-2, agencies were contacted with preliminary data and plans for permit applications. This coordination provided guidance as to the agencies' involvement, potential permit scope and requirements and identified pathways to shorten the future permitting process as much as practicable. The following describes the types of permits and the process to obtain all the required approvals to proceed.

Environmental Impact Assessment

A preliminary review of the environmental impacts has shown that there are no known endangered species, artefacts, surface water or ground water that will be impacted and that there would not be any noise issues in this area.

During FEL-2, the main project components/processes were reviewed for potential environmental impacts. No major issues were identified during these efforts. As the project evolves into full FEED and Financial Investment Decision (FID) activities, continued evaluation of potential environmental impacts shall be incorporated into the project plans.

The materials used in this project will be recyclable to the extent of what is required for any industrial process. Svante has a ''Cradle to Grave'' policy and therefore will manage the SAB replacement, reclaiming and recycling.

Carbon Capture Plant Permitting Process

Permitting for the carbon capture plant has been broken into the Construction Phase and the Operational Requirements. Some of these permits will require coordination with regulators to confirm compliance and to ensure they are open to the planned permitting strategy.

The permitting identification and execution process is part of the engineering design phase. Information defined during the feasibility/basic engineering in FEL-2 and the Detailed Engineering in the FEED study will be used for permit applications and any required meetings with related agencies.

The Colorado Department of Public Health and Environment checklist can be found at:

https://www.colorado.gov/pacific/sites/default/files/AP_APEN-Permit-Exempt-Checklist.pdf

Certain facilities within the state of Colorado may be exempt from some of the following permits. The permits listed below are considered likely to be required and worth additional investigation during the FEED study.

Table 7 - Required Construction Permits

Construction			
Permit Name	**Agency**	**Time Required**	**Notes**
Construction Storm Water (COR400000)	CDPHE	3 weeks	Required for disturbance of 1 acre or more.
Construction Air Permit	CDPHE	3-6 months	May be required depending on the facility design and ownership. While carbon capture is not a listed use, it is similar to listed Special Uses. A Special Review Use Permit will likely be required including a Planning Commission meeting and a County Board meeting. General APEN; exemption for stationary internal combustion engines with emissions of less than 5 tons per year for each individual criteria emitted. If it is owned by the existing facility, it would become a CUP/SUP amendment but that will not ultimately change the schedule or cost of the permitting. Application fee may be reduced to $500 for modification of an existing CUP/SUP.
NPDES Permits	CDPHE	1-3 months dependent on water stream	NPDES permit for construction (does not include SWPPP design) Dependent on field activity https://cdphe.colorado.gov/clean-water-permitting-sectors
Waste registrations (universal)	CDPHE	1 month	

Waste registrations (haz) EPA ID Number	CDPHE	1 month (unless CO has state specific process that takes longer) Dependent on the actual make-up of the non-hazardous waste. Colorado Department of Public Health & Environment requires permitting by waste type.	Dependent on types of wastes and volumes anticipated (most likely during commissioning)
Crane Inspection	TBD	TBD	FEED and constructability will inform
FAA registration	FAA	TBD	Dependent on height of cranes- TBD if this is required- FEED and constructability review will better inform
Waste Management Plan	No agency review required	N/A	Construction review

The Operational Permits are listed below. Some entries require a sign-off or certification and are not actual permits. Most of the permits listed below are obtained through CDPHE.

Table 8 - Required Operational Permits

Owner/Operations				
Permit Name	Agency	Time Required	Next Steps	Notes
Modifications to Kiln Air Permit	CDPHE	12-14 months	Review existing permit and perform emission calculations to determine strategy for revision.	Amend existing air permit for Lafarge site: add gas fired steam generator and possibly a diesel fired emergency fire pump

Owner/Operations				
Permit Name	Agency	Time Required	Next Steps	Notes
New Pressure Vessel Registration	Colorado State Division of Oil and Public Safety 7 CCR 1101-5 (CO OPS)	Inspection Schedule: ● New boilers by State Inspector prior to entering service (no cost for this inspection) ● Power/High Temp Boilers inspected annually ($100 for this inspection) ● Pressure vessel insurance reports need to be kept current or an inspection can be ordered within 60 days of expiration. ● Inspection of boilers or pressure vessels built outside of Colorado require an inspection prior to shipment. Inspector must be a valid National Board Commission inspector. ● Application filed by owner/user prior to installation.	FEED stage to identify and list pressure vessels (≥4 cu ft); instrument air; reservoirs	Owner / Developer team or EPC delegate to register new pressure vessels per CO regulations
Fire Protection	Fire Marshall	● Identify quantities of flammable/explosive/corrosive materials ● Initiate contact prior to construction mobilization (~60 days prior).	FEED Team to identify Authority Having Jurisdiction (AHJ) for Fire Protection. Identify quantities of flammable/explosive/corrosive materials	Kiewit team to identify Authority Having Jurisdiction (AHJ) for Fire Protection. Certification and review of drawings.

Owner/Operations				
Permit Name	Agency	Time Required	Next Steps	Notes
		● Building drawings, storage of hazardous materials information, project construction and commissioning schedule, and construction safety procedures should be in hand for the preliminary meeting with the Fire Marshal. ● Primary contact information, inspection dates, drawing review periods, and insurance information requirements should be outcomes from this meeting.		
Wetlands Impacts (404)	USACE	Timeline: 12 -14 months	Pre-application Meeting: pre-application meeting with the USACE to review the project and proposed impacts prior to submittal of an application. This will help streamline the permitting process by engaging the reviewing agency early.	Dependent on footprint of activity- cost to be refined once footprint is confirmed
ESA Consultations-Federal	USFWS/NMFS(unlikely)	30 days from formal request for review	In depth review of species and habitat overlap with project area in next round of review	23 species listed in the county; suggest in depth review of these species and habitat overlap with project area in next round of review

Owner/Operations				
Permit Name	Agency	Time Required	Next Steps	Notes
ESA Consultations-State	CO Parks and Wildlife	30 days from formal request for review	In depth review of species and habitat overlap with project area in next round of review	74 species listed in the state; suggest in depth review of these species and habitat overlap with project area in next round of review
Historic Property/Significance Consultations	CO SHPO	TBD	Additional review in next round of review	Unlikely to be huge influence on project as this is previously disturbed area currently used for industrial purposes; suggest additional review in next round of review
Waste Registration-HAZ	CDPHE	• 1 month (unless CO has state specific process that takes longer) • Dependent on the actual make-up of the non-hazardous waste. • Colorado Department of Public Health & Environment requires permitting by waste type.	Update existing registrations	Update existing registrations; break out into Universal versus Haz Waste; absorbent materials will be replaced approx. 5-7 years
Solid Waste Generation	CDPHE	• Dependent on the actual make-up of the non-hazardous waste. • An application for an EPA ID# is likely required.	Update existing registrations	Update existing registrations

Owner/Operations				
Permit Name	Agency	Time Required	Next Steps	Notes
		● Annual waste activity reports are required for the life of the hazardous waste disposal.		
NPDES Operational Permit- Stormwater	CDPHE	Amend existing permit ● General timeframe for permit issuance is 10 - 21 days (closer to 10 days for amendment).	Amend existing permit	Drainage from site can tie into existing facility outfall
NPDES Operational Permit- Wastewater	CDPHE	Amend existing permit ● General timeframe for permit issuance is 10 - 21 days (closer to 10 days for amendment).	Amend existing permit	Wastewater can tie into existing on site water treatment as needed to meet effluent requirements
401 water quality certification	CDPHE	Timeline: 60 - 90 days (small to moderate projects), 6 - 12 months (large projects)	Pre-filing Request: pre-filing request to the CO Department of Public Health and Environment (CDPHE). A mandatory 30-day pre-filing review follows during which time CDPHE staff review the pre-filing request information and may request a pre-filing meeting.	Update existing 401 certification as needed; https://cdphe.colorado.gov/401%20Certification
EPCRA	CDPHE	Annual reporting and coordination with local agencies	Identify volume and type of chemicals anticipated on site	Based on volume and type of chemicals anticipated on site (construction and operations); cost is reflective of annual reporting effort

Owner/Operations				
Permit Name	Agency	Time Required	Next Steps	Notes
SPCC	EPA	3 months	Update existing SPCC	Utilize existing SPCC; update as needed within 6 months of transition to operational SPCC
FAA registration	FAA	TBD	Conduct feed study	New stack for cleaned flue gas FEED study required to understand height of stack and design/registration requirements and if registration applies to the stack
Pressure Relief Devices	CO State Division of Oil and Public Safety	N/A	N/A	Colorado does not have a specific requirement for pressure relief valve inspections based on a review of 7CCR 1101-5
Water Permit	Division of Water Resources	TBD	Before this water is appropriated, the individual or entity must submit an application for a water permit containing a plan (whether to divert, store, or otherwise capture, possess and control) that specifies the amount of water to be used, type of beneficial use, and the locations of diversion or storage.	Need coordinates/location of potential intake to confirm "first in time, first in right". Confirming industrial use is beneficial use (ref. slide 12 https://www.coloradomesa.edu/water-center/documents/2019-

Owner/Operations				
Permit Name	Agency	Time Required	Next Steps	Notes
				colorado-water-law-basics.pdf)

CO_2 Pipeline Permitting Process

The Pipeline and Hazardous Materials Safety Administration (PHMSA) has the primary responsibility of issuing Department of Transportation (DOT) special permits and approvals for hazardous materials which include natural gas and hazardous liquid pipelines. A liquid CO_2 pipeline would also be considered by the PHMSA for permits. Approvals authorize the transportation of designated hazardous materials or the performance of a designated hazardous materials function under the PHMSA regulations.

The typical Federal and State Permits required for pipeline in Colorado are presented in Appendix G.

CO_2 Storage Permitting Process

Sheep Mountain Unit (SMU)

The Sheep Mountain Unit (SMU) includes Federal, State, and Fee surface and mineral ownership. Permissions and agreements will be put in place with these entities to convert the SMU from a producing CO_2 source field into a site for the permanent geologic CO_2 sequestration. Under these agreements, the SMU would serve as a CO_2 hub sequestration site, and production of CO_2 would be permanently terminated.

Suitable wells that can be converted to UIC Class VI CO_2 injection wells are already in place.

The injection wells will fall under the EPA's Class VI UIC classification. These permits are issued by the EPA, as Colorado has not yet obtained primacy for them. The monitoring wells will be re-permitted from CO_2 producers into CO_2 monitoring services through the Colorado Oil and Gas Conservation Commission regulations.

Finally, a Monitoring, Reporting, and Verification plan will be put in place for the SMU. This MRV Plan is required for EPA Subpart RR reporting of CO_2 and other greenhouse gases that are geologically sequestered. This plan will contain the following items as set forth in 40 CFR Part 98.449 – MRV Plan Requirements:

- Facility Information
- Project Description
- Delineation of maximum monitoring area (MMA) and active monitoring area (AMA)
- Identification of potential leakage pathways
- Strategy for leakage detection and quantification – monitoring plan
- Strategy for establishing baselines
- Summary of site-specific factors in mass balance
- Proposed date to begin data collection for purposes of mass balance
- QA/QC program
- Recordkeeping

OLCV obtained the first two (2) MRV plans that were issued by the EPA and currently holds MRV plans for three (3) of its CO_2-EOR projects. shows the most important permits and plans required to use SMU as a CO_2 Hub sequestration site.

Table 9 - Two Permits/Plans required for CO2 Hub Sequestration at SMU

Agency	Permit Name	Notes	Duration
US EPA – UIC Program (Water Office)	UIC Class VI	Sheep Mountain Unit has existing geological and reservoir characterization work available.	Application preparation – 6 to 12 months EPA review and approval - 12 to 24months
Us EPA.GHGRP (Air Office)	MRV Plan	Assumes Class VI permit. MRV will be an add-on with technical work already completed. This work cannot be started until after the geo. and eng. data acquisition needed for UIC Class VI (12 - 24 months)	Prerequisite - Class VI UIC geo. and eng. data acquisition Application preparation - 2 to 3 months EPA review and approval - 2 to 4 months

The UIC Class VI post injection period is set at 85 years by default and MRV reporting is required until the operator can provide an EPA authorization for site closure.

CO_2-EOR

Both the SCFU and WODC units CO_2-EOR projects are regulated by the Texas Railroad Commission (TRRC) and include a combination of permitted injector, producer, and disposal wells (ref. Appendix G). The injector wells are subject to the Underground Injection Control (UIC) Class II regulations. In Texas, Class II wells that are injecting water undergo additional regulatory review before commencing CO_2 injection. Both fields currently have water and CO_2 injectors, and the regulatory process to add any new CO_2 injectors is routinely completed within 3–4 weeks.

As UIC Class II projects, both SCFU and WODC units would opt into the Greenhouse Gas Reporting Program (GHGRP) by submitting a MRV plan for each field. OLCV's experience with three (3) approved MRV plans at existing CO_2-EOR projects located in the Permian Basin of West Texas will facilitate the development of MRV Plans for SCFU and WODC units. Both CO_2-EOR projects share general site characteristics and risk profiles with the other EOR projects with approved MRV plans. Therefore, the process for developing and gaining approval of MRV plans for each field is expected to be similar. It is anticipated that each MRV plan can be developed and go through the approval process within a 3-month period.

Project Closure

UIC Class II permits allow for closure at the end of injection and the GHGRP allows UIC Class II projects to discontinue reporting prior to site closure, provided it can make the appropriate demonstration pursuant to 40 CFR Part 98.441(b)(2)(ii) for non-UIC Class VI wells "that current monitoring and model(s) show that the injected CO_2 stream is not expected to migrate in the future in a manner likely to result in surface leakage." Because of the extensive well history and reservoir characterization that is a by-product of CO_2-EOR projects like these, the period of time required for this demonstration is expected to be brief once the decision has been made to stop accepting new CO_2 for permanent storage into these projects.

Subtask 3.7 – Capital & Operating Cost Estimates

Estimate Basis

The purpose of the capital cost estimate during FEL-2 is to generate an AACE Class IV cost estimate. This is a more thorough and accurate assessment compared to the cost estimate obtained in FEL-1. At each stage gate, the quality of the definition improves and enables the preparation of the capital and operating cost estimates, with an increasing level of accuracy as previously shown in Table 3 – CAPEX Estimate Accuracy Guidelines .

The basis of the estimate covers the carbon capture plant for the LH CO_2MENT COLORADO project including the Svante VeloxoTherm™ process equipment and associated inside battery limit (ISBL), the CO_2 compression system and the interconnection CO_2 pipeline options described in Subtask 3.5.

The carbon capture plant capital cost estimate has been prepared by Svante & Kiewit based on a Class IV cost estimate with a range of accuracy of -15%/+20% and project definition of 10% to 20%. The estimation methodology is a semi-detailed analysis with assembly level line items for installation from the purchased equipment cost. The FEL-2 team was also able to obtain current vendor pricing quotations for boilers, blowers, heat exchangers, direct contact coolers, and compressors. These items were priced specifically for FEL-2 designs and represent a level of detail higher than for a typical Class IV estimate, for improved cost accuracy. The estimation methodology is a material take-off (MTO) estimate for the site development, feed flue gas interconnection piping from the HOLCIM cement stack to the direct contactor cooler, and local labor rate, see Basis of Estimate and the Cost Estimating Plan in Appendices I-2 and I-3 for a list of guidelines.

The FEL-2 estimate results describe not only the total plant cost, but also the cost per area of the carbon capture plant. This cost-per-area approach will allow the Svante/Kiewit team to demonstrate which components of the carbon capture plant drive cost, feasibility, and schedule. In turn, this will help identify future projects that are best suited for an economic carbon capture plant. It can also contribute to enact value engineering on the most impactful areas during the FEED stage. See Figure 31 for cost area mapping and breakouts.

The FEL-2 team benefits from local recent experience in similar construction projects, leading to good accuracy in local labor rates. In addition, the feed flue gas interconnection duct and rack from the cement stack to the carbon capture plant had high-level structural 3D modeling and quantity take-off, leading to a higher accuracy than for a typical Class IV estimate for that specific scope.

In producing the capital cost estimate used in this TEA, Svante/Kiewit have adopted the naming conventions specified by the US Department of Energy (DOE) in their document "Cost Estimation

Methodology for NETL Assessments of Power plant Performance (DOE/NETL-2021/22550), where costs for this Class IV TEA are estimated at four levels:

Purchased Equipment Costs (PEC), while not a NETL/DOE cost level, will be cited in this report to aid in comparison to previous cost estimate work

- Purchased Equipment Costs (PEC)
- Bare Erected Costs (BEC): PEC + Supporting Facilities, Materials, Bulks/Commodities, and Direct & Indirect Labor Expense
- Total Plant Cost (TPC): BEC + Engineering, Construction, Management, Home Office & Contractor Premiums, Allowances & Freight, and Process & Project Contingencies.
- Total Overnight Costs (TOC): TPC + Pre-Production Costs, Inventory Capital, Financing Costs and Other Owner Costs (where applicable).

DOE cost estimation levels were expanded to describe the seven (7) cost areas of the carbon capture plant, see Figure 31 for details. This granularity was added to allow a cost-per area approach. The team notes that the Additional BOP Equipment and Civil Infrastructure costs (Areas 3 & 4) are similar or the same for many of the carbon capture technologies that might be employed for the project, including amine carbon capture solutions.

Infrastructure Cost Estimate

HOLCIM site specific infrastructure and characteristics include:

- Buildings
- Site Development
- Roads
- Drainage
- Utilities
- Water Treatment
- Grading
- Substations
- Feed flue gas piping interconnection from the HOLCIM cement plant to the carbon capture plant
- The following infrastructure costs have been added to the Svante's BEC estimate:
- Site development
- Feed flue gas piping
- Utility connections

Purchased Equipment Costs (Carbon Capture Plant)

For the purpose of this FEL-2 estimate, a large percentage of the Purchased Equipment Costs (PEC) were calculated based on heat and mass balance data, specified in standard Kiewit specifications, and priced with current vendor quotations. For low-cost equipment where Kiewit has extensive accurate and recent pricing, equipment was sized using calculations, and costs were scaled using standard process engineering scaling factors. Kiewit historical database of recent carbon capture projects as well as power generation projects (where applicable) was also used to validate major process equipment and packages.

The PEC for FEL-2 equipment is estimated at $113.9 MM. This is the plant equipment cost for all BOP equipment as well as the RAM cost.

Bare Erected Costs

In developing the capital cost estimate for the FEL-2 TEA, Svante/Kiewit has utilized Kiewit's vast estimating/historical/factoring experience to generate a Class IV AACE estimate. Indirect costs including construction equipment, tools, scaffolding and bulk materials have been estimated alongside direct labor and supporting facilities using Kiewit's extensive historical values for this type of work in this region.

The FEL-1 used an overall percentage of direct labor expense, which is a broad method of pricing appropriate for a pre-feasibility study estimate. For this FEL-2 Class IV estimate, items like construction equipment and tools/small tools were priced for the specific area, specific work, and summed for an overall cost. This realistic and granular approach improves on the accuracy that a broad percentage provides.

The BEC for the FEL-2 capital cost estimate is estimated at $292.8M.

Total Plant Cost

In FEL-1, material and direct labor costs were calculated using an overall percentage of PEC. The FEL-2 team went to the next level of detail and priced material and direct labor costs for each discipline or type of cost, and did so for seven (7) different plant areas. Local labor rates, historical labor agreements, and historical productivity factors were utilized within the cost estimate. As previously discussed, these seven (7) area costs, were used to evaluate the true cost of the carbon capture plant relative to the site-specific costs.

As noted previously, the Site Specific BOP and Civil Infrastructure costs are much the same, regardless of the carbon capture technology utilized.

The estimating process applied cost factors for engineering expenses, construction management, home office and contractor premiums, process and project contingencies in order to bring the BEC estimate of $292.8MM to a Total Plant Cost (TPC) estimate of $383.9. These factors are in line with recent Kiewit estimates for similar projects.

Total Overnight Costs

The FEL-2 effort has taken the above TPC, with markup and premiums, along with the applicable Owner's costs (legal fees, permitting, Owner's management reserve, Owner's Engineer, etc.) to represent the Total Overnight Cost (TOC) for the HOLCIM Carbon Capture Plant, utilizing a June 2019 cost basis. This TOC value is estimated at $ 411.5MM.

Explanation of Cost Areas

The estimate is broken into areas of the plant, as well as into Kiewit cost codes. The following sections explain the areas and cost codes for further understanding. The methodology of the AACE Class IV estimate can be found in the separate Cost Estimating Plan document in Appendix I-3.

As explained above, the FEL-2 estimate divided the total cost into seven (7) areas to demonstrate where costs lie (ref. Figure 31). Site-specific items like site infrastructure, substations, and site BOP make a notable impact to the total cost coming in at above 30%. Choosing the right site for a plant is key, but the FEL-2 estimate quantifies this selection and provides meaningful data for evaluation of the HOLCIM site, and other future Svante Carbon Capture sites. Examples of the many site-specific influences are listed below.

If a site has waste heat integration capabilities that could generate steam, this could negate some or most of the Area 5 costs. If a location is using the CO_2 product for oil recovery and could use lower quality and lower pressure CO_2, the costs for Area 7 will decrease notably compared to the above price. Sites with available power feeds not requiring a substation would see Area 6 cost drop to almost nothing. A site with space immediately adjacent to the CO_2 source would have reduced steel and ductwork for moving flue gas to a carbon capture plant, thus reducing the cost in Area 3.

At the HOLCIM site, over 1,000 ft of large diameter ductwork and supporting steel needs to span a rising elevation from the cement plant to the carbon capture plant site, raising Area 3 costs significantly. Should an existing facility have spare cooling capacity or cooling water available, a portion of Area 3 dedicated to cooling would not be required. As seen above, Area 3 has an impactful cooling tower cost. Area 3 cost would also be lower at a facility not requiring independent warehouse, parking and administration buildings.

A site that is less undulating and hilly than HOLCIM would have lower civil cut and fill costs, as well as lower grading and storm water costs. The quality of flue gas also has an impact. Facilities with cleaner burning natural gas require less clean-up of the moisture that drops out of the flue gas, reducing costs in Area 3. Sites burning coal, rubber, or other less refined fuels will have more extensive water treatment capital and operational expenses.

As these various areas reduce in footprint and cost, Area 4 will also decrease in cost along with standard overhead and contingency costs, further compounding the cost reductions.

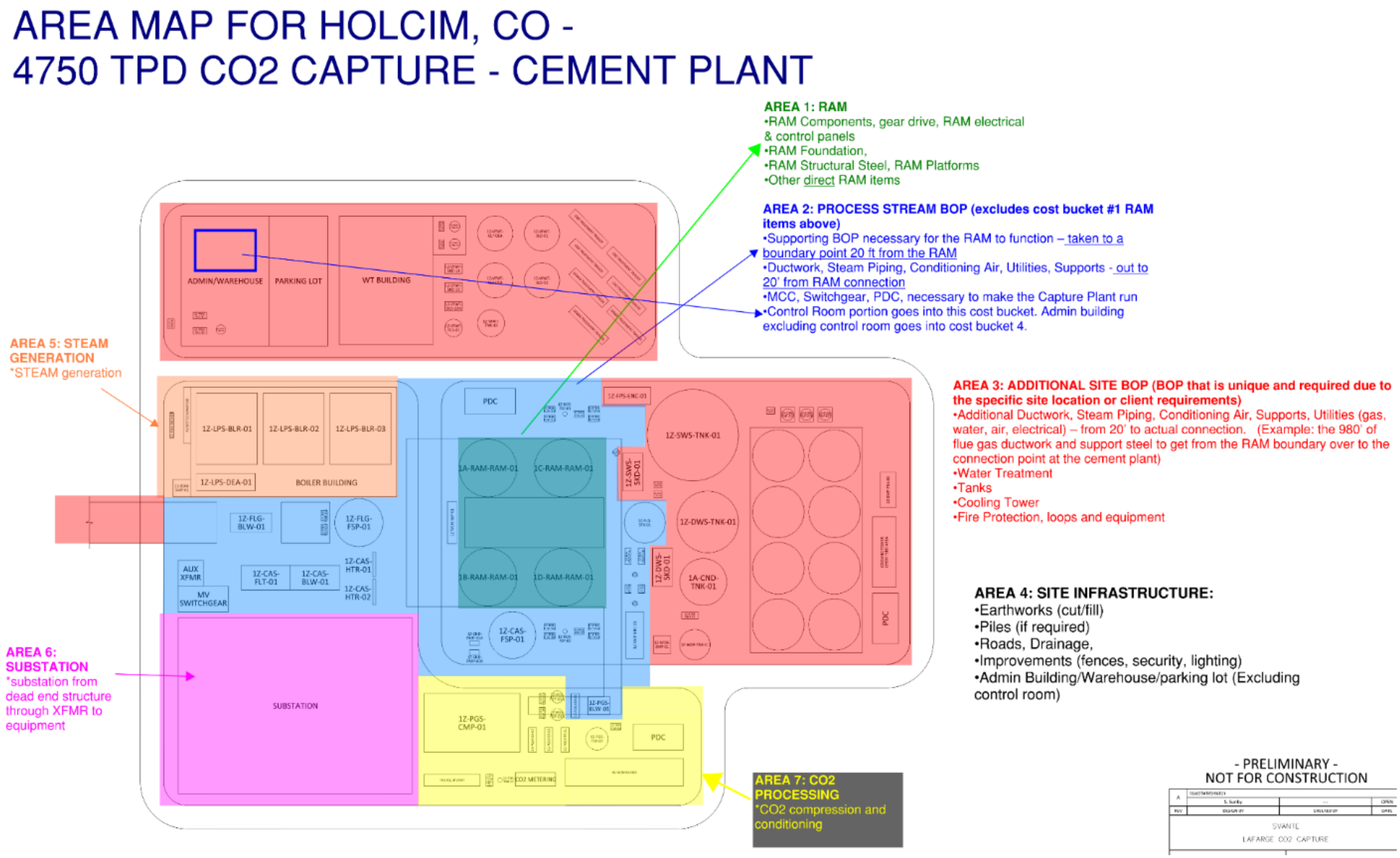


Figure 31 - Cost areas layered on the HOLCIM plot plan

It is particularly important to note that areas 3-7 are largely independent of carbon capture technology. While there are some nuances with each technology such as various pumps and heat exchangers for amine technologies or sorbent costs for solid sorbent technologies, almost all types will require site-specific steam, plant cooling, electric power, CO_2 product conditioning, and general site infrastructure. It is the low relative cost of the Svante RAM that makes it a highly competitive option for carbon capture at a wide variety of facilities.

Cost Reduction Opportunities

The Explanation of Cost Area section details how the HOLCIM site compares to other site locations, and reviews cost savings from site to site. When focusing specifically on the HOLCIM site, there are unique opportunities for cost reduction that will be examined in the FEED stage. Due to the nature of a FEL-2 estimate, not everything about a facility is known. The FEL-2 path dictated a carbon capture plant that is essentially a standalone facility, with minimal cement plant thermal and process integrations. A prime area of focus of the FEED will be to capitalize on any integration possibilities. Some focal points are:

Substation – At $4.9 million dollars, the substation represents a small percentage of the plant cost. However, continued discussions with the utility will occur during the FEED to assess the need for a substation, and the components that will be included in that substation. Additionally, further discussions with HOLCIM regarding the planned expansion of the cement facility shall be undertaken to optimize the integration of the expansion with the carbon capture facility in order to reduce the overall installed cost.

RAM – Svante is debuting the URSA 1000 and URSA 2000 RAM series shortly, and with this will come opportunities for constructability cost reductions, space optimization to reduce plant footprint, as well as quantity and labor reductions. This next generation of equipment will be fully evaluated in the FEED to enhance efficiency in the field and reduce capital costs.

Reflux/Conditioning Air Trains – Svante has improved the efficiency and design of the cycle during the FEL-2 stage. Initial estimates indicate this may represent around $3,000,000 in potential savings. The FEED stage should provide a space to demonstrate those gains in terms of lower capital cost for piping, ductwork, pumps, vessels, and fans.

Wastewater – The plan for wastewater generated at the carbon capture plant is to send the clearwell overflow to the HOLCIM cement plant. In return the cement plant will use that wastewater for typical back-end processes, and the cement plant can send some raw water to the carbon capture plant. The cement plant water consumption is not changed. Only the quality and amount of raw water that the carbon capture plant receives is improved. This design path will be further validated in the FEED stage through coordination with HOLCIM. Exact water quality limits will be defined, and the water treatment equipment will be further optimized. Potential for equipment size reduction or deletion exists, depending on the limits of water quality that HOLCIM holds.

Facility resources – The cost of security, fencing, and administrative space can be reduced since the carbon capture plant is included near an existing site, and can share some of the original site parking, fencing, security or other facilities, if HOLCIM agrees. Sharing these systems further reduces the carbon capture plant capital expenses. This will be re-examined in closer detail in the FEED stage to seek additional savings.

Steam – If any waste heat is available for use at HOLCIM, the FEED will further examine the practicality and economics of using the waste heat to generate steam. This could reduce steam generation capital costs as well as operating costs.

Equipment technology – The FEL-2 team obtained quotes from vendors for sized mechanical equipment. This process involved performing calculations for equipment sizing and comparing competing vendor quotes and technologies to select the best equipment at the lowest cost. While not typical for a Class IV estimate, this extra effort was made on a handful of the largest cost equipment. During the FEED stage, the equipment pricing process will be carried out more in depth, generating actual real-time equipment quotations for the majority of the plant scope. This activity will provide a multitude of benefits from getting accurate vendor technical data, more accurate and lower overall equipment prices, and accurate real-time escalation quantification. Escalation in the past 24 months has been a much more impactfully variable than in previous years. This up-to-date vendor pricing will paint a clear picture of the cost to build a carbon capture facility in 2022 and beyond.

General – With an above-mentioned reduction in FEED study equipment comes further reduction in the foundations and civil works that support that equipment. With each reduction in quantity and cost realized during the FEED, comes an additional reduction in the overhead that supports that work. With each reduction in scope, another reduction in contingency and risk costs will appear. The work of the upcoming FEED study will further compound cost improvements to increase the viability of constructing a carbon capture plant at HOLCIM.

Pipeline Capital Cost

The options for transportation and sequestration of CO2 captured from the Holcim facility include sequestration at Sheep Mountain or EOR at two existing sites in the Permian Basin. The EOR option at the Salt Creek Field Unit and Wasson Old Denver City is expected to yield the lowest overall cost due to the slightly lower pipeline capital cost and fees realized from the field operator.

Cost Estimating Plan

The FEL-2 Cost Estimating Plan and the detailed efforts performed during the estimation phase is found within Appendix I-3.

Operating Cost Estimate

The purpose of the operating cost estimate is to update the TEA scoping study performed based on the advanced project definition and FEL-2 scope. The basis of estimate covers the carbon capture plant for the LH CO_2MENT COLORADO project, including the Svante VeloxoTherm™ process and associated natural gas fired auxiliaries and CO_2 compression system. The facility is assumed to operate at nearly 100% capacity for all but one month out of the year.

The sequestration fees for the CO_2 storage options have been provided by OLCV, including pipeline and storage fees.

Electricity, Natural Gas and Water Costs

Table 10 provides a summary of the utility's cost, namely for natural gas, electricity and water consumptions. The variable operating costs for each have been calculated using existing local cost for the

HOLCIM cement plant and potential reduced cost based on the renewable power option described in Subtask 3.1.

The natural gas consumption is a direct correlation with the steam ratio (amount of steam required per amount of CO_2 product).

Table 10 - Summary of Target Utility Costs

Consumption Rate			
Utility			**Unit Cost**
Natural Gas Consumption			$2.63/MMBTU
Electrical Power Target Price			$40.00/MWh
Potable Water Consumption			$4.60/1,000 gal
Raw Water Consumption			$2.18/1,000 gal
Sanitary Sewer Disposal			$2.30/1,000 gal

Natural gas to the HOLCIM cement plant is provided by a regional Gas transmission Company .

Electricity to the HOLCIM cement plant) is provided by a local power company. The current line capacity to the Portland substation is limited. Therefore, upgrades to the line conductors to the plant may be required in order to supply the required electrical load of the carbon capture plant and cement plant expansion. To determine the water consumptions, a Water Balance Flow Diagram was generated using the Water Balance Flows at 3 COC.

Operation and Maintenance Costs

In FEL-1, direct operational expenses were estimated based on a broad factored estimation methodology, including operating labor (1.5 operators) & supervisory labor (30% of operating labor), operating supplies (15% of maintenance & repairs) and maintenance & repairs (1.5% of PEC). Fixed operation and maintenance expenses were estimated on a factored estimation methodology, including property taxes & insurances (1% of 75% insured value of TPC) and overheads & administration (20% of direct expenses).

During FEL-2, the team developed operational and maintenance costs in greater details. Prime drivers for operation and maintenance costs are electricity and natural gas consumption, which are a symptom of any carbon capture technology. Even with the low cost of electricity of $0.04/kW targeted for HOLCIM, the electricity cost is still the second largest operational cost of the carbon capture plant.

The operational cost is based on 30 days of outage time per year. Other than those outage times, the operation is assumed 24 hours a day, 7 days a week. Operational costs will decrease if the facility is not operated as often as assumed.

The operational costs calculated for the facility have been incorporated in the Financial Model Simulation Results presented in Figure 1. The simulation also addresses the possible impact of variability in electricity and natural gas pricing. The ranges selected for the sensitivity analysis fall within early 2022 forecasts from NREL and the EIA for Solar PV electricity costs and Natural gas prices through 2050.

Bed Replacement Cost

Structured Adsorbent Bed (SAB) replacement costs are assumed to be incurred approximately every 5 years and treated, from an accounting point of view, as ''sustaining capital''. The SABs will be monitored for pressure drop, CO_2 capture recovery and CO_2 product purity to determine the optimum bed replacement time. The bed lifetime can be extended based on these measurements. Bed productivity and lifetime have been estimated using the Svante's data modeling and pilot plant performance field testing and the optimum time for each step in the process cycle.

Svante is currently scaling-up its SAB manufacturing facilities at the new Svante World Headquarters located in Burnaby, BC, with an annual capacity of about 1,500 m^3 of stacked bed, equivalent to about 3 million m^2 of laminate. This first commercial manufacturing plant is scheduled to be in operation by Q4-2023 The bed replacement sustained capital is estimated at $14,615,000, equivalent to $2.92 per tonne of CO_2 for a 5-year lifetime.

CO_2 Sequestration Fees

The sequestration fees presented in the FEL-1 report for the two storage options considered in FEL-2 were updated according to the evaluation work described above. The fees discussed previously are February 2022 cost basis.

The Sheep Mountain CO_2 sequestration fee includes insurance to protect against any unexpected leakage of CO_2 that would result in the invalidation of CO_2 credits generated by this Carbon Capture Sequestration (CCS) project. Tariffs for the 'new' pipeline and the 'SMPL East' are for transport of CO_2 from the cement plant to the Sheep Mountain CO_2 storage field.

The CO_2 EOR fees estimated in FEL-1 are still valid and were employed in FEL-2 fee calculations, as the two (2) CO_2 EOR projects selected to store the CO_2 from the LH CO_2MENT COLORADO project are existing projects with well understood costs. Only the pipeline tariff for the 'new' pipeline was revised due to the material and labor costs increases previously mentioned. The 'SMPL South' tariff was not modified from FEL-1 because it too is an existing line with well understood costs. Tariffs for the 'new' pipeline and the 'SMPL South' are for transport of CO_2 from the cement plant to the SCFU and WODC CO_2 EOR projects.

Subtask 3.8 - Hazard and Operability Study (HAZOP)

In order to support project due diligence, a risk review/HAZOP review was performed based upon the information available during the FEL-2 level of the project. A more detailed and comprehensive HAZOP analysis shall be preformed during the FEED phase of the project, building upon further project definition and refinement of design, construction and operations parameters.

The detailed Hazard and Operability Study was conducted and facilitated by a third-party specialist company, Hanearin Strategic Inc.

Task 4.0 – Engineering Design Report

The Final Engineering Design Report is encompassed within the various sections of this FEL2 report and the Appendices as listed in the Table of Contents.

Subtask 4.1 – Inside Balance of Plant (ISBL)

The Subtask 3.2 section above covers extensive ISBL information. Additional context for Subtask 4.1 is contained within the process/systems descriptions, operating parameters, technical approaches and solutions contained in the previous sections of this report and within the Appendices as listed in the Table of Contents.

Subtask 4.2 – Outside Balance of Plant (OSBL)

The Subtask 3.3 section above covers extensive OSBL information. The detailed utility requirements, tie-in locations and other optimized interface points are detailed within previous sections of this report and within the Appendices as listed in the Table of Contents.

Subtask 4.3 – Field Cost Analysis

The updated project cost information is contained within Section 3.7 of this report.

Subtask 4.4 – Commercial Site Approval

The Owner of the Host Site, following advancement of the identified Owner/Developer tasks, the completion of the FEED study, and a positive recommendation regarding the Financial Investment Decision (FID) will obtain all internal and/or corporate approvals required to proceed with the detailed design and construction of the project.

Task 5.0 Technology Assessment

Subtask 5.1 EH&S Risk Assessment

An EH&S Risk Assessment was prepared for the project. This assessment considers key areas of potential Environmental, Health and Safety risk including stability, toxicology, volatility, flammability, and also addresses regulatory considerations associated with the use of Svante's sorbent and RAM technologies in commercial scale project. These factors are discussed in the following sections.

Material Stability and Toxicology

The adsorbent selected for the cement plant application is CALF-20 MOF, which is being scaled up for commercial manufacture. The material is stable to water (liquid, steam) and Oxygen (Air) up to 325°C and is much more stable to NOx and SOx when compared with Amine based CO_2 Capture adsorbents. This is particularly important as NOx and SOx both exist in Cement flue gas streams.

Further performance durability and stability tests on CALF20 laminate have shown that the adsorbent beds showed no significant change (below experimental measurement errors) in any of the measured Key Performance Indicators (KPIs) of productivity, purity, and steam ratio.

An independent expert conducted official toxicity and corrosivity testing on Svante's adsorbent using certified laboratories. Findings from their analysis determined that the materials are stable, inert, and non-hazardous however have the potential to pose a risk of eye irritation during the manufacturing process.

Volatility, Flammability, Explosivity, other Chemical Reactivity, and Corrosivity

Solid adsorbents, like CALF-20 MOF, have inherent advantages over liquid amine systems which exhibit solvent loss through evaporation as well as degradation during operation. Solid adsorbents are made of non-hazardous materials, do not generate waste by-products or fugitive emissions, and do not pose significant environmental, health, or safety risks, a significant advantage to operators of the systems. Structured Adsorbent Beds (SAB) are made from micron size MOF particles coated in a carbon-based substrate, then stacked, packaged, and bonded inside fire resistance aramid/phenolic honeycomb fiber panels. It is however important to note that the beds (filter) will be delivered complete from the manufacturing process, plant operators will have no exposure to the raw materials.

The following table summarizes the material test results prepared by the independent laboratory.

Table 11 - Material Test Results

Components	**Material**	**Volatility**	**Flammability**	**Corrosivity**	**Reactivity**	**Hazardous**	**Disposal Considerations**
Adsorbent	Calf20 MOF	Stable	No specific fire hazard. Standard firefighting precautions including SCBA.	Non-corrosive, mild irritant	Stable to water and air up to 325C	eye irritation. No other known effects or critical hazards	Dispose at license industrial site.
Substrate	Carbon fiber	stable	Material will burn until polymeric binder is burn out	Inert	Inert	Carbon fiber - non-hazardous Polymeric binder - non-hazardous	Non-hazardous, dispose at license industrial site
Packaging	Fiberglass, Nomex	Stable	Unknown. Standard firefighting precautions including SCBA.	Inert	Stable	Non-hazardous in cured form	Non-hazardous, dispose at license industrial site
Epoxy	Epoxy	Stable	Unknown. Standard firefighting precautions including SCBA.	Inert	Stable	Non-hazardous in cured form	Non-hazardous, dispose at license industrial site
Bellow	EPDM, Nylon	Stable	Unknown. Standard firefighting precautions including SCBA.	Inert	Stable	Non-hazardous	Non-hazardous, dispose at license industrial site
End cap	Noryl plastic	Stable	NFPA rating: 1. Standard firefighting precautions including SCBA. Estimated autoignition temperature 490°C.	Inert	Stable	Non-hazardous	Non-hazardous, dispose at license industrial site

Compliance and Regulatory Implications

Toxic Substances Control Act (TSCA) – Svante's SABs do not contain known chemicals that require record keeping and reporting to the EPA such as PCBs, asbestos, lead, mercury, formaldehyde, and certain hexavalent chromium compounds.

Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) – None known, material used for manufacturing of SABs can be disposed of at licensed waste disposal sites.

Clean Water Act (CWA) - Svante Carbon Capture system does not use chemicals in the gas separation process. Condensates generated from the process can be collected and treated by the facility and returned to the process.

Clean Air Act (CAA) - Svante Carbon Capture system does not generate regulated pollutants. Emission levels from the carbon capture stack will less than or equal to the source Kiln flue gas emissions. The stack gas exhausted from the Carbon Capture system after CO_2 has been removed from the flue gas is primarily N_2, O_2, H_2O plus air from the conditioning steps.

US EPA UIC Program – UIC Class VI injection well permit application will be required for CO_2 storage/sequestration solutions.

US EPA MRV Plan – A Monitoring, Recording and Verification Plan will be submitted for review and approval as required for the Underground Injection Control solution.

US DOT/PHMSA – Design, Construction and Operation of hazardous material pipeline

HAZID

In order to support project due diligence, a risk /HAZOP review was performed based upon the information developed during the FEL-2 study project.

The scope of the HAZOP was limited by the level of engineering and design detail completed at FEL-2 and will be utilized to inform the design of the FEED effort. However, no significant risk factors were identified by the review panel, comprising an independent 3rd Party facilitator supported by senior staff members of the project engineering team.

Engineering Analysis of Potentially Hazardous Materials

Hydrogen – In order to meet pipeline purity standards, Oxygen will be removed from the product stream using an hydrogenation process. Pure H_2 is produced and compressed to 550 psig prior to being mixed with CO_2. Hydrogen production and storage is a well proven unit operation, standard industry practice will be followed to minimize and manage risk. An alternate method of O_2 reduction will be considered in future phases of design, for example cryogenic distillation.

CO_2 dense phase/liquid transportation - All options for handling CO_2 product utilize transportation by high pressure pipeline. Pipeline transportation of CO_2 is a well-established process with an excellent safety record. Safety considerations required by state and federal regulations are considered in the design, construction and operations of the pipeline system.

Process Vent, Solid and Wastewater Streams

Process Vent

Any contaminants present in the kiln flue gases that pass through the inlet treatment process will continue through the adsorbent beds and will be vented through the carbon capture plant stack. This includes N_2, O_2, CO, NO, light hydrocarbons, etc. However, the majority of gaseous and particulate contaminants, which could include SO_2 and NO_2, will be removed in the DCC/pre-treatment phase and will be discharged for treatment in the condensate system.

Wastewater

To reduce overall plant water treatment requirements condensate streams produced at various stages of the process will be collected and recycled.

- Clean condensate streams will be segregated for re-use in boiler water make up streams.
- Streams from the cooling tower blowdown and flue gas treatment systems will be combined and treated separately. Suspended solids from the stream will be filtered, the dewatered filtrate will be trucked off-site for disposal at a licensed industrial waste site. Clarified water will be returned to the cement plant for re-use. Alternatives to treatment/re-use investigated by the study include the implementation of zero-liquid discharge technology, this will be reviewed further in future phases of design.

Solid

Structured Adsorbent Module disposal – The Svante sorbent materials are classified as non-hazardous. At end of life, the sorbent modules will be tested and disposed of in a licensed industrial waste site in conjunction with State and Federal rules.

Wastewater system filtrate will be disposed of in a licensed industrial waste site in conjunction with State and Federal rules.

Subtask 5.2 TEA

The FEL-2 TEA Summary Report has been created in response to project "LH CO_2MENT COLORADO" and to accelerate the implementation of a 1.5 million tonnes per year (TPY), and first-of-a-kind (FOAK) at world scale, Svante VeloxoTherm™ carbon capture plant. This project represents a quantum leap to a large-scale facility that will launch Svante's carbon capture technology into the next era of accomplishments and market acceptance. By completing the Front-End Loading (FEL) Feasibility Study Report (FEL-2) for a fit-for-purpose design at the Holcim cement plant, located near Florence Colorado, USA, this technology can be proven as the future of large-scale deployment for carbon capture and storage.

This carbon capture plant was designed with the goal of reaching a target of near Net Zero Emissions by capturing 90% of the carbon dioxide (CO_2) emissions from the HOLCIM cement plant and from the natural gas fired auxiliary systems required for the carbon capture plant. Additionally, this project bases the COE assuming parallel development of a renewable Power Purchase Agreement (PPA) using solar energy at the target price of 0.04 $/kWh or less. The existing CO_2 emissions of the HOLCIM cement plant is around 700 – 800 kg/ton of clinker produced. The proposed new carbon capture plant will allow a reduction of CO_2 emissions to about 100 kg/ton of clinker produced.

The TEA includes required elements as applicable to the technology:

• General process flow diagram identifying all major process equipment for the power plant including CO_2 capture and compression systems, separation vessels, heat exchangers, pumps, compressors, etc.

• Material and energy balances around the complete power plant and around all major pieces of equipment there in, including all heating and cooling duties, and electric power requirements

• Complete stream tables showing operating pressures, temperatures, compositions, and enthalpies for all streams entering or leaving major process equipment

• Economic analysis that follows the NETL "Quality Guidelines for Energy System Studies: Cost Estimation Methodology for NETL Assessments of Power Plant Performance" The code of accounts for the capital cost estimate will follow those used in the BBS. Operating and maintenance cost follow the format used in the BBS.

• Estimates for equipment and consumables unique to the process being developed.

The scope of the Class 4 TEA consists of the process design and capital & operating cost estimation for a total plant capacity of 4,750 TPD of pipeline grade CO_2. The Svante VeloxoTherm™ technology is comprised of a Rotary Adsorption Machine (RAM) for intensified Thermal Swing Adsorption (TSA) using Structured Adsorbent Beds (SABs) and related Balance of Plant (BOP), including CO_2 compression.

The methodology used for the economic assessment is outlined in the Capital and Operating Costs section of this report. The purpose of the TEA is to outline the high-level economics of Svante's technology applied to a 4750 TPD, point source, Carbon Capture facility.

In producing the capital cost estimate used in this TEA, Svante/Kiewit have adopted the naming conventions specified by the US Department of Energy (DOE) in their document "Cost Estimation Methodology for NETL Assessments of Power plant Performance (DOE/NETL-2021/22550). Costs are reported at 4 levels as follows;

• Purchased Equipment Costs (PEC)

• Bare Erected Costs (BEC): PEC + Supporting Facilities, Materials, Bulks/Commodities, and Direct & Indirect Labor Expense

• Total Plant Cost (TPC): BEC + Engineering, Construction, Management, Home Office & Contractor Premiums, Allowances & Freight, and Process & Project Contingencies.

• Total Overnight Costs (TOC): TPC + Pre-Production Costs, Inventory Capital, Financing Costs and Other Owner Costs (where applicable).

Note - Purchased Equipment Costs (PEC), while not a NETL/DOE cost level, will be cited in this report to aid in comparison to previous cost estimate work performed during an earlier phase of the project.

Calculated Output Results from the Analysis:

- Purchased Equipment Costs (PEC) of $113.9M. This is the plant equipment cost for all BOP equipment as well at the RAM cost.

- Bare Erected Cost (BEC) of $292.8M.
- Total Plant Cost (TPC) of $383.9M
    - The FEL-2 team priced material and direct labor costs for each discipline or type of cost and did so for seven (7) different plant areas. Local labor rates, historical labor agreements, and historical productivity factors were utilized within the cost estimate.
- Total Overnight Costs (TOC) of $411.5M
    - The FEL-2 effort has taken the above TPC, with markup and premiums, along with the applicable Owner's costs (legal fees, permitting, Owner's management reserve, Owner's Engineer, etc.) to represent the Total Overnight Cost (TOC) for the Holcim Carbon Capture Plant, utilizing a June 2019 cost basis.

Sensitivity Analysis against Base Case

A business case (financial analysis) evaluation has been undertaken as part of this study. This analysis has relied on a detailed and comprehensive Project Financial Model, evaluating the Total Project IRR (after tax, unlevered, and including all forecast 45Q PTCs and 100% tax efficiency) – the project financial analysis (as opposed to standard TEA analysis) only considered a 12-year plant economic lifetime as a result of 45Q being the sole driver considered at this stage. The Total Project IRR was evaluated across a large number of potential scenarios as described below and demonstrated that if the 45Q PTD is increased to $85/MT for sequestration, there are a large number of feasible scenarios which demonstrate economic returns.

As identified within the DOE capital cost summary and evaluations, there are a number of key economic drivers which can have a significant impact on the financial performance of the project. In order to address this degree of variability in key assumptions, the detailed PFM model was used in conjunction with a custom-written script to simulate more than 10,000 different project financial model scenarios across the following key economic drivers:

- Capital De-Escalation
- Natural Gas Price
- Electricity Price
- CO_2 T, S&M Charge
- DOE Funding Grant Levels
- Plant Operating Rate (onstream factor)

An abbreviated summary of the results of this simulation across these variables, in terms of Total Project IRR, is presented in the heat map in Figure 1. As can be seen from the results of the simulation activity, there are a large number of scenarios for the project which are economically feasible. Ranges of utility costs used for additional sensitivity analyses and the impact in $/tonne are provided in the heat map.

Note: Significant challenges across industrial projects worldwide have occurred because of the impacts of the COVID pandemic. Large increases and escalations of equipment and supply chain costs have occurred over the last two years, often increasing the overnight capital costs of projects by 20% to 40%. These levels of financial impacts on capital costs have not been seen in the last two decades and the ability to forecast where the price of commodities and equipment is severely hampered by the challenges and volatility within the worldwide supply chain and labor markets.

Subtask 5.3 State Point Data Table

The bed and laminate properties presented in the State Point Data Table estimated from testing conducted on the Svante VTS with CALF20 material (with 20% CO_2 in Feed).

The VTS is a test station where a single bed is exposed to the different streams (Feed Gas, Superheated steam, Ambient air) during specific periods of time to simulate a full adsorption/regeneration/ conditioning cycle. This methodology has been used to scale up and define the cycles on all other test stations at Svante and have been validated during operational testing (0,1 TPD PDUs, 1TPD CO_2MENT pilot, 25 TPD PPCU).

Table 12- State Point Data Table

	Svante equivalent quantity	Units	Measured/ Estimated Performance	Projected Performance
Sorbent				
True Density @ STP	Weight/ Bed Volume	kg/m^3	350-380	350-380
Bulk Density		kg/m^3	NA	NA
Average Particle Diameter*	Adsorbent particle diameter	mm	0.31-0.35	0.31-0.35
Particle Void Fraction		m^3/m^3	NA	NA
Packing Density	Wetted sheet area / bed volume	m^2/m^3	2300-2500	2300-2500
Solid Heat Capacity @ STP	-	kJ/kg·K	1.4-1.6	1.4-1.6
Crush Strength		kg_f	NA	NA
Attrition Index		-	NA	NA
Thermal Conductivity	-	W/(m·K)	0.25-0.35	0.25-0.35
Adsorption				
Pressure	-	bar	1 – 1.1	1 -1.1
Temperature	-	°C	50	50
Equilibrium Loading	20% CO_2	gmol CO_2/kg	1.7-1.9	1.7-1.9

Heat of Adsorption	-	kJ/gmol CO_2	35-38	35-38
CO_2 Adsorption Kinetics	-	gmol/g min	1.4	1.4
Desorption				
Pressure	-	bar	0.8-1.0	0.8-1.0
Temperature	-	°C	120-140	120-140
Equilibrium Loading	20% CO_2	gmol CO_2/kg	0.3-0.4	0.3-0.4
Overall Performance				
Space Velocity	-	hr^{-l}	1093	1093
Volumetric Productivity	-	TPD/m^3	8-12	12-15
Carbon Capture Efficiency	-	%	90-95	92-96
Pressure Drop	-	kPa	10	5
Degradation (life time)		Years	3	5

Definitions used in State Point Table

STP – Standard Temperature and Pressure (15 °C, 1 atm)

Sorbent – Adsorbate-free (i.e. CO_2-free) and dry material as used in adsorption/desorption cycle.

Adsorption – The conditions of interest for adsorption are those that prevail at maximum sorbent loading. These may be assumed to be 1 atm total flue-gas pressure (corresponding to a CO_2 partial pressure of 0.13 bar) and 40°C.

Desorption – The conditions of interest for desorption are those that prevail at minimum sorbent loading. Operating pressure and temperature for the desorber/stripper are process dependent.

Pressure – The pressure of CO_2 in equilibrium with the sorbent. If the vapor phase is pure CO_2, this is the total pressure, and if it is a mixture of gases, this is the partial pressure of CO_2.

Average Particle Diameter – MOF Adsorbent particle diameter (CALF-20) in the laminated sheet

True Density – weight of adsorbent/bed volume

Packing Density – Ratio of the laminated sorbent composite sheet area/ filter bed volume.

Equilibrium Loading – The basis for CO_2 loading is mass of dry sorbent measured with 20% CO_2 in N_2 mixture without moisture.

Kinetics – A characterization of the CO_2 adsorption/desorption trend with respect to time, as complete in the range of time as possible.

Space Velocity – volume of feed per volume of bed per cycle multiply by number of cycles per hour assuming a 20% CO_2 concentration in the feed.

Volumetric Capacity – tonnes per day of CO_2 capture per volume of structured laminated bed (filter)

Carbon Capture Efficiency – % of incoming CO_2 that is captured under expected operating conditions in a single pass.

Pressure Drop – average per pass pressure drop across the bed (filter) plus transition ducts.

Degradation – 3 to 5 years lifetime without bed replacement with negligible capacity fade (% decrease over 100 cycles).

The Next Steps

Key Areas for Action

As the FEL-2 phase progressed, the team identified key areas for action, further investigation, and value engineering opportunities to be addressed during the next steps of the project. The establishment of an Owner/Developer and executing associated tasks is a key to further the LH CO_2MENT COLORADO project in areas beyond the assessment of the FEL-2 report and lead up to start the FEED phase and to FID.

Key Owner/Developer tasks that are required to advance and provide guidance and information into the FEED phase, as well as provide inputs into the Financial Investment Decision (FID), which include:

- Identification of a renewable energy source and execution of a power purchase agreement at $0.04 cents a kilowatt or lower.
- Execution of an electrical interconnect agreement for the supply of electricity to the carbon capture plant.
- 115kV Power Supply: The current power supply to the facility runs along the northwest side of the carbon capture plant and is operated at 115kV. If this power line is used, the current power demand will require a design review of this line. Owner developer to negotiate power supply and interconnect agreements and provide input to FEED design. The conductors may require replacement or additional conductors added. A Power Study will be done to define this requirement and any cost associated.
- Assessment of the potential for electrical integration opportunities with the HOLCIM cement plant and planned expansion of the cement plant quarry operations. Future plans of the HOLCIM cement plant will be taken into account to avoid interferences and find synergies with the construction and operation of the carbon capture plant.
- Execution of an integrated water supply agreement for the carbon capture plant
- Site Location: Options for the location of the carbon capture plant and the orientation of the site components and plot plan may require adjustments to optimize cost. Utility connections and flue gas interface could lead to modification of the current plan. The modularization of plant components will impact construction costs along with orientation of major components.

- Wastewater agreement may need to be negotiated for the disposal of this wastewater stream. This could include a disposal plan or recycle to the cement plant.
- Analysis of opportunities for maximum integration with the cement plant to be conducted during FEED. Cost benefit reviews of impacts of modifying of existing systems and components within the cement plant leading to lower capital costs and lower operating costs for the carbon capture plan.
- Evaluation of relative environmental, air, water, data interconnect, land use, pipeline requirements and permits. Ownership of the existing permits, development of new permits and interconnection requirements will impact schedule, design and costs. The pipeline will require planning to address rights of way and maintenance access.
- Flue gas constituent variability is an area that will need further definition during FEED design. Fuel mix and air uptake in the cement process will impact the constituents and thus the cost of the plant to meet specifications. This will require a cement plant review beyond the initial discussions to determine which factors can be changed to limit some constituents.
- Owner Developer to set parameters around flue gas constituent variability and impacts to the water treatment system. The fuel mix contains petroleum coke, rubber and occasionally plastic. These inputs carry constituents that will impact the wastewater treatment system. Some constituents are difficult to recycle or remove from the water, thus will impact the cost of the water treatment system.
- Compressor configuration and optimization is a process concern and requires modeling and vendor support. As the project progresses, the time and expertise available to challenge the present design will become available. Further coordination with compressor manufacturers will be undertaken to evaluate changes in the product design that may be relevant to the carbon capture, transport, and storage market. This will also require dynamic modeling to adjust for load following the cement plant.
- Risk and Opportunity Matrix to be further defined to identify key areas of project impacts. These areas marked for evaluation represent potential impacts and opportunities for further project definition, design evolutions and enhancements, as well as maintaining a strong focus on cost reduction opportunities. For example, if Saline Aquifer is a valid sequestration option, the level of CO2 compression and conditioning requirements could be reduced, saving significant capital costs and operating values. Conversely, if the project risk profile identifies that the use of wet cooling is a significant a risk due to the Site location, the Owner may elect to utilize air coolers with a higher capital cost and auxiliary load value.
- As each action, investigation and value engineering activity is completed during FEED, key decisions regarding the project will be made in order to determine the best path forward. The integrated project schedule will maintain updates on the progress of these actions. Additionally, monthly reporting will identify the impacts, cost reductions, and capture the key decisions made and the reasons behind these decisions. Also, a robust Risk Register will be utilized to present the project risks, opportunities and mitigation strategies.
- Secure funding for a full FEED study to advance the project into the next phase.

Some specific areas for action, investigation and value engineering are identified below. The project team is continuing to identify key aspects to be addressed during the beginning of the FEED phase in order to provide information on the progression of the design, estimated costs and project financial pro-forma.

Optimization Analysis

Kiewit and Svante have prepared a White Paper to better document some of the challenges, assessments, and decision paths that the feasibility study team embarked on during the execution of the FEL-2 efforts. The White Paper identifies areas for optimization and further investigations to be evaluated during the FEED stage of the project. Additionally, these efforts shall better inform decision paths made for similar carbon capture facilities in the future.

CO_2 Transportation and Storage Assessments

The CO_2 transportation and storage assessments will continue in the FEED phase of the project as a key driver for success of the overall project. Emphasis will be placed on the most up-to-date CCS credit and incentive information required to make the final determination of which of the sequestration options will be selected for the dense phase CO_2. With this information, an optimized project plan can be created and evaluated.

Renewable Power Generation

There have been two (2) alternative power generation options evaluated: PV solar power and renewable energy (Specialized Power Cycle Plant). The goal is the achieve $0.04 or less per kW of renewable energy to support the project. Further optimizations of renewable power generation option to also be a key driver for the success of the overall project.

Summary Statement

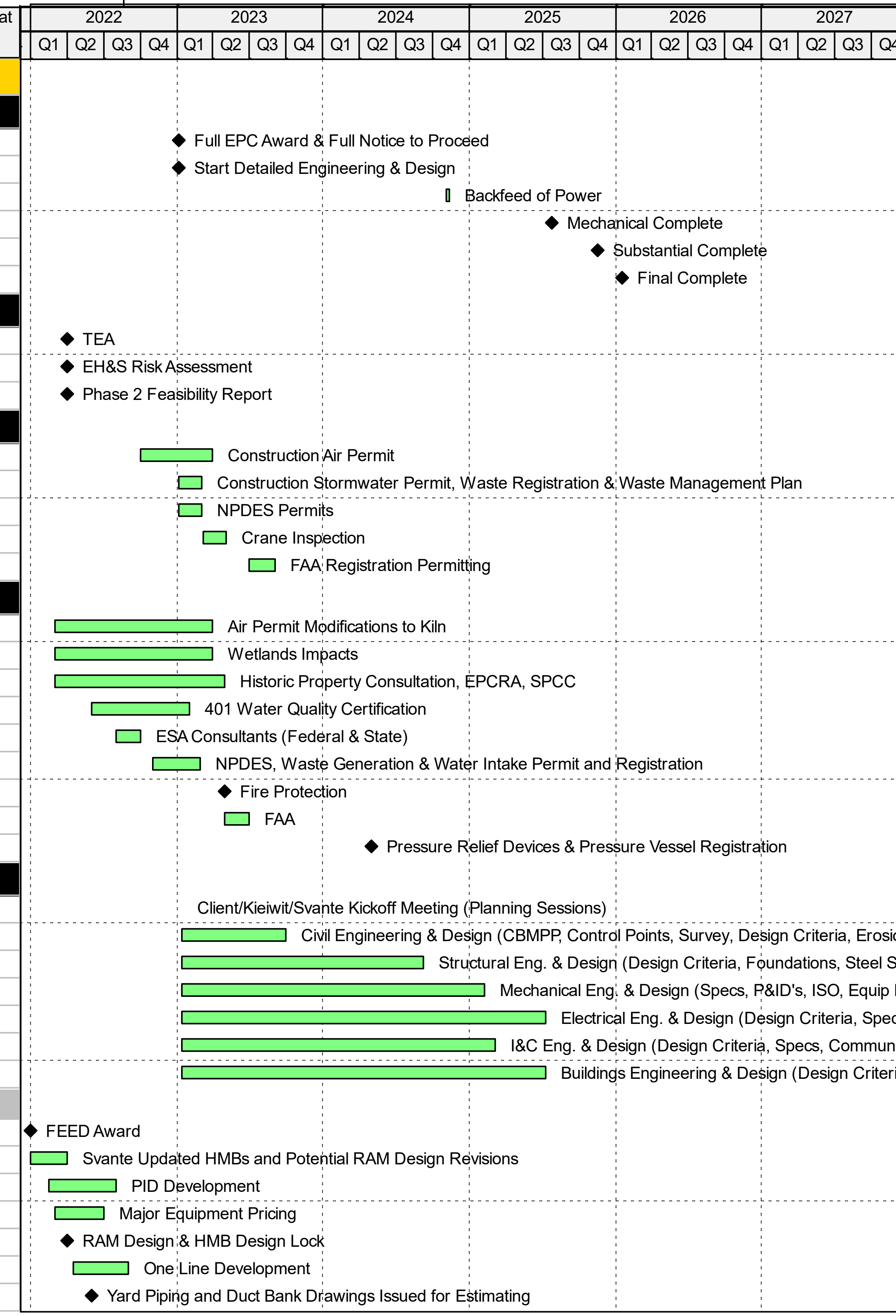
The FEL-2 team has been honored and privileged to be part of the DOE sponsored efforts to advance the potential carbon capture plant utilizing Svante's VeloxoTherm™ technology at the HOLCIM, CO cement plant facility. While many challenges and opportunities have been identified and require further advancements, the solutions are viable and achievable. Further support from the DOE, Owner/Developer advancements, project definition and optimization opportunities will increase the strong probability of a successful commercial implementation of a carbon capture plant in the cement industry at this location.

Kiewit

Svante - LafargeHolcim Carbon Capture

Printed: 24-Feb-22

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
Svante - LafargeHolcim Carbon Capture		1013	02-Jan-22	16-Jan-26	0
Project Milestones		762	04-Jan-23	16-Jan-26	0
A1000	Full EPC Award & Full Notice to Proceed	0	04-Jan-23*		0
A1020	Start Detailed Engineering & Design	0	04-Jan-23		5
A2650	Backfeed of Power	5	05-Nov-24*	11-Nov-24	294
A2300	Mechanical Complete	0	24-Jul-25		81
A2310	Substantial Complete	0	17-Nov-25*		0
A2320	Final Complete	0	16-Jan-26		0
DOE Milestones		0	31-Mar-22	31-Mar-22	950
A2350	TEA	0		31-Mar-22*	951
A2360	EH&S Risk Assessment	0		31-Mar-22*	951
A2370	Phase 2 Feasibility Report	0		31-Mar-22*	951
Construction Permitting		326	01-Oct-22	01-Sep-23	841
A2380	Construction Air Permit	177	01-Oct-22*	01-Apr-23	991
A2390	Construction Stormwater Permit, Waste Registration & Waste Management Plan	60	05-Jan-23*	05-Mar-23	1018
A2400	NPDES Permits	60	05-Jan-23*	05-Mar-23	958
A2410	Crane Inspection	60	06-Mar-23*	05-May-23	958
A2420	FAA Registration Permitting	61	01-Jul-23*	01-Sep-23	842
Owner Permitting		770	01-Mar-22	01-May-24	606
A2430	Air Permit Modifications to Kiln	386	01-Mar-22*	01-Apr-23	991
A2440	Wetlands Impacts	386	01-Mar-22*	01-Apr-23	991
A2490	Historic Property Consultation, EPCRA, SPCC	415	01-Mar-22*	01-May-23	962
A2450	401 Water Quality Certification	238	01-Jun-22*	02-Feb-23	1049
A2480	ESA Consultants (Federal & State)	61	01-Aug-22*	01-Oct-22	1167
A2460	NPDES, Waste Generation & Water Intake Permit and Registration	115	01-Nov-22*	01-Mar-23	1022
A2470	Fire Protection	0		30-Apr-23*	964
A2500	FAA	61	01-May-23*	01-Jul-23	902
A2510	Pressure Relief Devices & Pressure Vessel Registration	0		01-May-24*	607
Engineering		883	02-Jan-22	09-Jul-25	130
A1010	Client/Kieiwit/Svante Kickoff Meeting (Planning Sessions)	2	11-Jan-23	12-Jan-23	0
A1030	Civil Engineering & Design (CBMPP, Control Points, Survey, Design Criteria, Erosion Control, Storm Drain, Site Plan etc)	180	13-Jan-23	28-Sep-23	8
A1040	Structural Eng. & Design (Design Criteria, Foundations, Steel Support/Access, Typical Concrete & Steel Details etc)	415	13-Jan-23	05-Sep-24	35
A1050	Mechanical Eng. & Design (Specs, P&ID's, ISO, Equip Modeling, Mech Detail Drawings/Lists, General/Equip Arrangement et	520	13-Jan-23	06-Feb-25	15
A1060	Electrical Eng. & Design (Design Criteria, Specs, Grounding, Ductbank, Cables, One Line, Tray Plans, Arch Flash, etc)	625	13-Jan-23	09-Jul-25	29
A1070	I&C Eng. & Design (Design Criteria, Specs, Communication, Instrument Install, Location Plan, ,IO List, etc)	540	13-Jan-23	06-Mar-25	19
A1080	Buildings Engineering & Design (Design Criteria, Specs, Layout etc)	625	13-Jan-23	09-Jul-25	22
FEED Study		340	02-Jan-22	15-Dec-22	1093
A2520	FEED Award	0		02-Jan-22*	1434
A2530	Svante Updated HMBs and Potential RAM Design Revisions	89	02-Jan-22*	01-Apr-22	1345
A2550	PID Development	164	15-Feb-22*	01-Aug-22	1227
A2570	Major Equipment Pricing	121	01-Mar-22*	01-Jul-22	1256
A2540	RAM Design & HMB Design Lock	0		01-Apr-22	1345
A2560	One Line Development	136	16-Apr-22*	01-Sep-22	1196
A2580	Yard Piping and Duct Bank Drawings Issued for Estimating	0		01-Jun-22*	1287



Remaining Level of Effort ◆ ◆ Milestone
Remaining Work

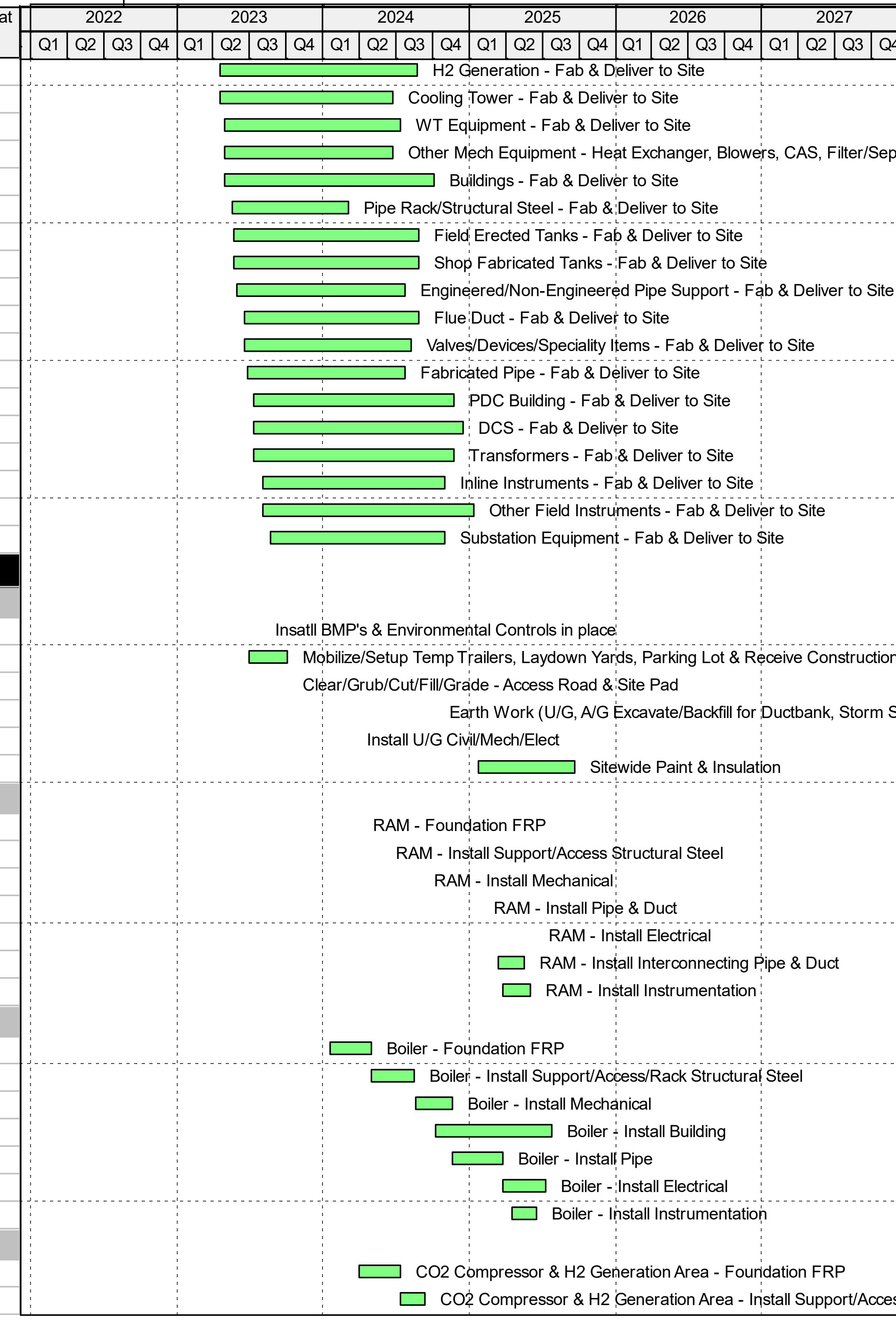
TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
A2600	Foundations & Steel Drawings Issued for Estimating	91	01-Jun-22*	01-Sep-22	1196
A2590	Iso's Issued for Estimating	61	01-Jul-22*	01-Sep-22	1196
A2610	Initial Circuit Schedule Issued for Estimating	32	01-Aug-22*	01-Sep-22	1196
A2620	Begin Class 2 Estimate	103	01-Sep-22*	15-Dec-22	1094
A2630	Estimate Review	15	01-Dec-22*	15-Dec-22	1094
A2640	FEED Study, Price & Proposal Due	0		15-Dec-22*	1094
Documents/Deliverables (Client, Svante & Vendors)		185	13-Jan-23	05-Oct-23	93
A1090	RAM (GA, Loads, Equip/Load List, Data Sheet, Shop Drawings, Details, I/O List, etc)	65	13-Jan-23	14-Apr-23	75
A1100	Boilers (GA, Loads, Equip/Load List, Data Sheet, Shop Drawings, Details, I/O List, etc)	65	31-Mar-23	05-Jul-23	42
A1110	CO2 Compressor (GA, Loads, Shop Drawings, etc)	65	17-Apr-23	19-Jul-23	46
A1120	H2 Generation (GA, Loads, Shop Drawing, etc)	65	17-Apr-23	19-Jul-23	46
A1130	Cooling Tower (GA, Loads, Shop Drawing, etc)	75	17-Apr-23	02-Aug-23	87
A1140	WT Equipment (GA, Loads, etc)	75	01-May-23	16-Aug-23	77
A1150	Other Mech Equipment - Heat Exchanger, Blowers, CAS, Filter/Seperator, Pumps (GA, Loads, etc)	90	01-May-23	07-Sep-23	41
A1170	Buildings (GA, Loads, etc)	65	01-May-23	02-Aug-23	22
A1160	Field Erected Tanks (GA, Loads, etc)	95	22-May-23	05-Oct-23	73
A1190	Shop Fabricated Tanks (GA, Loads, etc)	90	22-May-23	28-Sep-23	98
A1180	Flue Duct (GA, Loads, etc)	75	20-Jun-23	05-Oct-23	71
Procurement		507	04-Jan-23	09-Jan-25	104
Spec to Award		162	04-Jan-23	23-Aug-23	89
A1310	Pipe Rack/Structural Steel - Spec to Award	95	04-Jan-23	17-May-23	17
A1200	RAM - (Kiewit/Svante review Spec provided by Svante and formally issue them)	45	13-Jan-23	16-Mar-23	0
A1210	Boilers - Spec to Award	55	13-Jan-23	30-Mar-23	34
A1220	CO2 Compressor - Spec to Award	65	13-Jan-23	14-Apr-23	32
A1230	H2 Generation - Spec to Award	65	13-Jan-23	14-Apr-23	32
A1240	Cooling Tower - Spec to Award	65	13-Jan-23	14-Apr-23	32
A1250	WT Equipment - Spec to Award	75	13-Jan-23	28-Apr-23	37
A1260	Other Mech Equipment - Heat Exchanger, Blowers, CAS, Filter/Seperator, Pumps - Spec to Award	75	13-Jan-23	28-Apr-23	41
A1270	Field Erected Tanks - Spec to Award	90	13-Jan-23	19-May-23	53
A1280	Buildings - Spec to Award	75	13-Jan-23	28-Apr-23	22
A1290	Flue Duct - Spec to Award	110	13-Jan-23	19-Jun-23	64
A1300	Shop Fabricated Tanks - Spec to Award	90	13-Jan-23	19-May-23	53
A1320	Engineered/Non-Engineered Pipe Support - Spec to Award	95	13-Jan-23	26-May-23	25
A1330	Valves/Devices/Speciality Items - Spec to Award	110	13-Jan-23	19-Jun-23	15
A1340	Fabricated Pipe - Spec to Award	115	13-Jan-23	26-Jun-23	25
A1350	PDC Building - Spec to Award	125	13-Jan-23	12-Jul-23	66
A1360	DCS - Spec to Award	125	13-Jan-23	12-Jul-23	51
A1370	Transformers - Spec to Award	125	13-Jan-23	12-Jul-23	66
A1380	Inline Instruments - Spec to Award	140	13-Jan-23	02-Aug-23	19
A1390	Other Field Instruments - Spec to Award	140	13-Jan-23	02-Aug-23	104
A1400	Substation Equipment - Spec to Award	155	13-Jan-23	23-Aug-23	29
Fabrication and Delivery		455	17-Mar-23	09-Jan-25	104
A1410	RAM - Fab & Deliver to Site	300	17-Mar-23	24-May-24	0
A1420	Aux Boilers - Fab & Deliver to Site	320	31-Mar-23	10-Jul-24	34
A1430	CO2 Compressor - Fab & Deliver to Site	340	17-Apr-23	21-Aug-24	32

Remaining Level of Effort ◆ ◆ Milestone
Remaining Work

TASK filter: All Activities

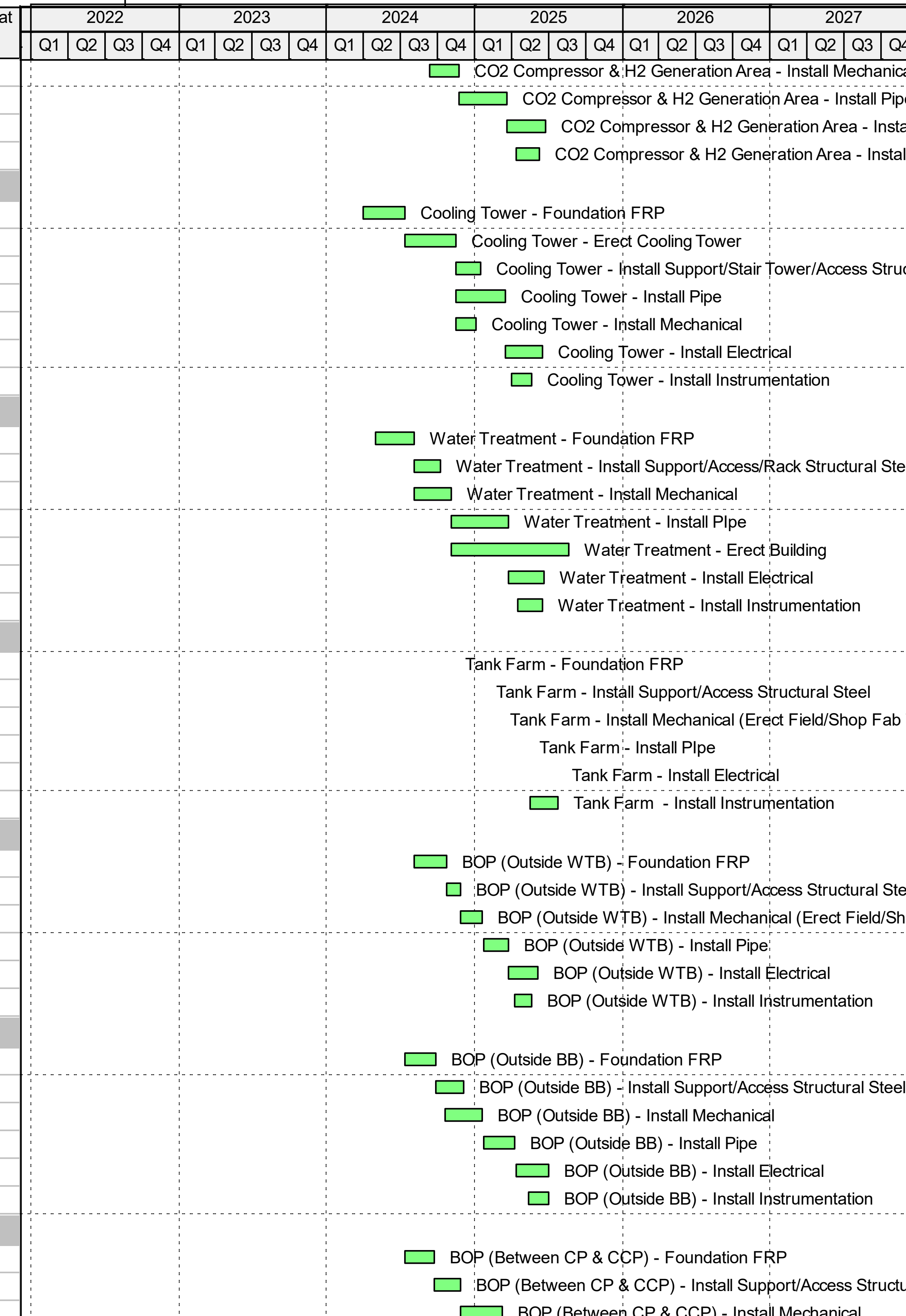
Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
A1450	H2 Generation - Fab & Deliver to Site	340	17-Apr-23	21-Aug-24	32
A1460	Cooling Tower - Fab & Deliver to Site	300	17-Apr-23	24-Jun-24	32
A1470	WT Equipment - Fab & Deliver to Site	300	01-May-23	10-Jul-24	37
A1480	Other Mech Equipment - Heat Exchanger, Blowers, CAS, Filter/Seperator, Pumps - Fab & Deliver to Site	290	01-May-23	24-Jun-24	72
A1500	Buildings - Fab & Deliver to Site	360	01-May-23	03-Oct-24	42
A1530	Pipe Rack/Structural Steel - Fab & Deliver to Site	200	18-May-23	05-Mar-24	17
A1490	Field Erected Tanks - Fab & Deliver to Site	320	22-May-23	28-Aug-24	53
A1520	Shop Fabricated Tanks - Fab & Deliver to Site	320	22-May-23	28-Aug-24	53
A1540	Engineered/Non-Engineered Pipe Support - Fab & Deliver to Site	290	30-May-23	24-Jul-24	25
A1510	Flue Duct - Fab & Deliver to Site	300	20-Jun-23	28-Aug-24	64
A1550	Valves/Devices/Speciality Items - Fab & Deliver to Site	285	20-Jun-23	07-Aug-24	15
A1560	Fabricated Pipe - Fab & Deliver to Site	270	27-Jun-23	24-Jul-24	25
A1570	PDC Building - Fab & Deliver to Site	345	13-Jul-23	21-Nov-24	66
A1580	DCS - Fab & Deliver to Site	360	13-Jul-23	16-Dec-24	51
A1590	Transformers - Fab & Deliver to Site	345	13-Jul-23	21-Nov-24	66
A1600	Inline Instruments - Fab & Deliver to Site	315	03-Aug-23	31-Oct-24	19
A1610	Other Field Instruments - Fab & Deliver to Site	360	03-Aug-23	09-Jan-25	104
A1620	Substation Equipment - Fab & Deliver to Site	300	24-Aug-23	31-Oct-24	29
Construction		557	30-Jun-23	18-Sep-25	80
Sitework/Underground		557	30-Jun-23	18-Sep-25	41
A1630	Insatll BMP's & Environmental Controls in place	18	30-Jun-23	27-Jul-23	0
A2210	Mobilize/Setup Temp Trailers, Laydown Yards, Parking Lot & Receive Construction Equipment	65	30-Jun-23	03-Oct-23	1
A1640	Clear/Grub/Cut/Fill/Grade - Access Road & Site Pad	48	28-Jul-23	04-Oct-23	0
A1650	Earth Work (U/G, A/G Excavate/Backfill for Ductbank, Storm Sewer, Foundations, etc)	250	05-Oct-23	02-Oct-24	0
A1660	Install U/G Civil/Mech/Elect	80	14-Nov-23	11-Mar-24	0
A2220	Sitewide Paint & Insulation	165	24-Jan-25	18-Sep-25	41
RAM		366	28-Dec-23	10-Jun-25	110
A1670	RAM - Foundation FRP	65	28-Dec-23	28-Mar-24	0
A1680	RAM - Install Support/Access Structural Steel	40	01-Apr-24	24-May-24	0
A1690	RAM - Install Mechanical	65	28-May-24	28-Aug-24	0
A1700	RAM - Install Pipe & Duct	100	29-Aug-24	23-Jan-25	0
A1710	RAM - Install Electrical	70	03-Mar-25	10-Jun-25	0
A1910	RAM - Install Interconnecting Pipe & Duct	46	12-Mar-25	15-May-25	17
A1900	RAM - Install Instrumentation	50	24-Mar-25	03-Jun-25	115
Aux Boilers		382	19-Jan-24	25-Jul-25	79
A1720	Boiler - Foundation FRP	72	19-Jan-24	30-Apr-24	7
A1730	Boiler - Install Support/Access/Rack Structural Steel	75	01-May-24	16-Aug-24	7
A1740	Boiler - Install Mechanical	65	19-Aug-24	18-Nov-24	7
A1920	Boiler - Install Building	200	08-Oct-24	25-Jul-25	79
A1750	Boiler - Install Pipe	85	19-Nov-24	24-Mar-25	7
A1760	Boiler - Install Electrical	75	25-Mar-25	11-Jul-25	7
A1890	Boiler - Install Instrumentation	45	15-Apr-25	18-Jun-25	104
CO2 Compressor & H2 Generation		312	01-Apr-24	25-Jun-25	99
A1770	CO2 Compressor & H2 Generation Area - Foundation FRP	70	01-Apr-24	10-Jul-24	1
A1780	CO2 Compressor & H2 Generation Area - Install Support/Access Structural Steel	45	11-Jul-24	12-Sep-24	17



Remaining Level of Effort ◆ ◆ Milestone
Remaining Work

TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
A1790	CO2 Compressor & H2 Generation Area - Install Mechanical	50	13-Sep-24	21-Nov-24	17
A1800	CO2 Compressor & H2 Generation Area - Install Pipe	80	22-Nov-24	20-Mar-25	17
A1810	CO2 Compressor & H2 Generation Area - Install Electrical	67	21-Mar-25	25-Jun-25	17
A1880	CO2 Compressor & H2 Generation Area - Install Instrumentation	40	11-Apr-25	09-Jun-25	111
Cooling Tower		307	01-Apr-24	18-Jun-25	143
A1820	Cooling Tower - Foundation FRP	70	01-Apr-24	10-Jul-24	22
A1840	Cooling Tower - Erect Cooling Tower	90	11-Jul-24	14-Nov-24	22
A1830	Cooling Tower - Install Support/Stair Tower/Access Structural Steel	40	15-Nov-24	16-Jan-25	251
A1850	Cooling Tower - Install Pipe	82	15-Nov-24	17-Mar-25	22
A2330	Cooling Tower - Install Mechanical	30	15-Nov-24	02-Jan-25	261
A1860	Cooling Tower - Install Electrical	65	18-Mar-25	18-Jun-25	22
A1870	Cooling Tower - Install Instrumentation	35	01-Apr-25	20-May-25	124
Water Treatment Building		330	01-May-24	22-Aug-25	59
A1930	Water Treatment - Foundation FRP	65	01-May-24	02-Aug-24	20
A1940	Water Treatment - Install Support/Access/Rack Structural Steel	45	05-Aug-24	07-Oct-24	40
A1950	Water Treatment - Install Mechanical	65	05-Aug-24	04-Nov-24	20
A1960	Water Treatment - Install PIpe	95	05-Nov-24	24-Mar-25	20
A1990	Water Treatment - Erect Building	200	05-Nov-24	22-Aug-25	59
A1970	Water Treatment - Install Electrical	62	25-Mar-25	20-Jun-25	20
A1980	Water Treatment - Install Instrumentation	45	15-Apr-25	18-Jun-25	104
Tank Farm Area		237	13-Aug-24	23-Jul-25	81
A2000	Tank Farm - Foundation FRP	55	13-Aug-24	29-Oct-24	0
A2010	Tank Farm - Install Support/Access Structural Steel	52	30-Oct-24	16-Jan-25	0
A2020	Tank Farm - Install Mechanical (Erect Field/Shop Fab Tanks, Skids etc)	65	13-Nov-24	18-Feb-25	0
A2030	Tank Farm - Install PIpe	52	19-Feb-25	02-May-25	0
A2040	Tank Farm - Install Electrical	54	05-May-25	22-Jul-25	0
A2050	Tank Farm - Install Instrumentation	45	19-May-25	23-Jul-25	81
BOP Area - Outside WT Building		210	05-Aug-24	04-Jun-25	114
A2060	BOP (Outside WTB) - Foundation FRP	55	05-Aug-24	21-Oct-24	32
A2070	BOP (Outside WTB) - Install Support/Access Structural Steel	25	22-Oct-24	25-Nov-24	32
A2080	BOP (Outside WTB) - Install Mechanical (Erect Field/Shop Fab Tanks, Skids etc)	35	26-Nov-24	20-Jan-25	32
A2090	BOP (Outside WTB) - Install Pipe	45	21-Jan-25	24-Mar-25	32
A2100	BOP (Outside WTB) - Install Electrical	50	25-Mar-25	04-Jun-25	32
A2110	BOP (Outside WTB) - Install Instrumentation	30	08-Apr-25	20-May-25	124
BOP Area - Outside Boiler Building		245	11-Jul-24	30-Jun-25	96
A2120	BOP (Outside BB) - Foundation FRP	55	11-Jul-24	26-Sep-24	14
A2130	BOP (Outside BB) - Install Support/Access Structural Steel	45	27-Sep-24	02-Dec-24	14
A2140	BOP (Outside BB) - Install Mechanical	62	18-Oct-24	20-Jan-25	14
A2150	BOP (Outside BB) - Install Pipe	58	21-Jan-25	10-Apr-25	14
A2160	BOP (Outside BB) - Install Electrical	55	11-Apr-25	30-Jun-25	14
A2170	BOP (Outside BB) - Install Instrumentation	35	12-May-25	30-Jun-25	96
BOP Area - Between Cement Plant & Carbon Capture Plant		258	11-Jul-24	21-Jul-25	1
A2230	BOP (Between CP & CCP) - Foundation FRP	52	11-Jul-24	23-Sep-24	1
A2240	BOP (Between CP & CCP) - Install Support/Access Structural Steel	46	24-Sep-24	26-Nov-24	1
A2250	BOP (Between CP & CCP) - Install Mechanical	70	27-Nov-24	11-Mar-25	1



Remaining Level of Effort ◆ ◆ Milestone
Remaining Work

TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
A2260	BOP (Between CP & CCP) - Install Pipe	35	12-Mar-25	30-Apr-25	1
A2270	BOP (Between CP & CCP) - Install Electrical	55	01-May-25	21-Jul-25	1
A2280	BOP (Between CP & CCP) - Install Instrumentation	30	22-May-25	07-Jul-25	11
Substation		150	01-Nov-24	09-Jun-25	29
A2180	Substation - Install Struc/Equip/Elect Gear/Controls	150	01-Nov-24	09-Jun-25	29
Admin/Warehouse		212	05-Aug-24	06-Jun-25	30
A2190	Admin/Warehouse - Foundation FRP	55	05-Aug-24	21-Oct-24	30
A2200	Admin/Warehouse - Erect Building	157	22-Oct-24	06-Jun-25	30
Startup & Commissioning		116	23-Jul-25	16-Nov-25	0
A2290	CCP - Pre-Commissioning & Commissioning	116	23-Jul-25	16-Nov-25	0

Remaining Level of Effort ◆ ◆ Milestone
Remaining Work

TASK filter: All Activities

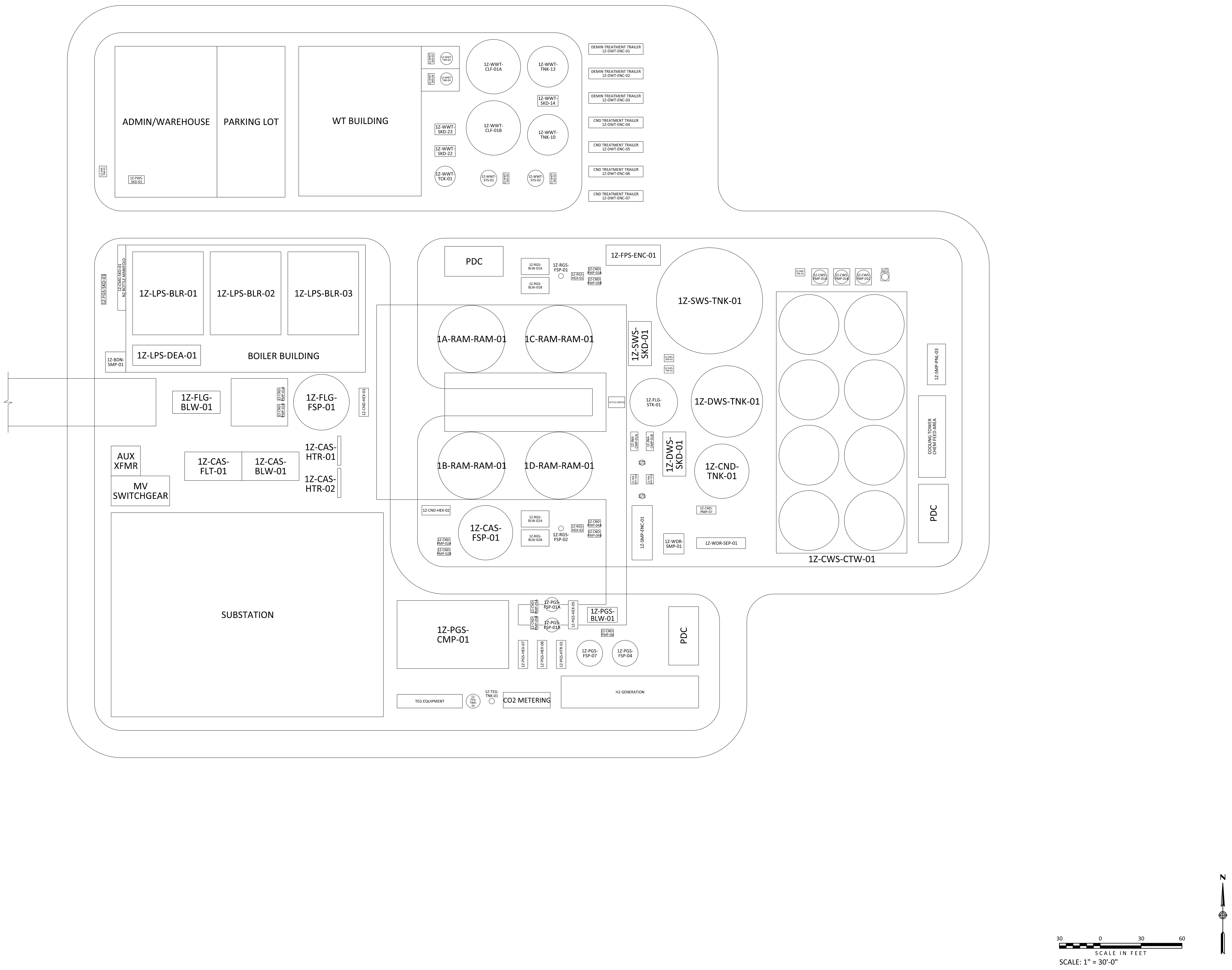
Appendix A-2

ID	Task Name	Original Duration	Start Date	Finish Date
1	**LaFarge Holcim to Sheep Mountain Pipeline Tie-in**	**660 days**	**Mon 1/3/22**	**Fri 7/12/24**
2	**FEED**	**109 days**	**Mon 1/3/22**	**Thu 6/2/22**
3	Project Kick Off	1 day	Mon 1/3/22	Mon 1/3/22
4	Preliminary Routing	10 days	Tue 1/4/22	Mon 1/17/22
5	HCA & EFRD Study	20 days	Tue 1/18/22	Mon 2/14/22
6	Preliminary PFDs	20 days	Tue 1/18/22	Mon 2/14/22
7	Environmental Desktop Review	20 days	Tue 1/18/22	Mon 2/14/22
8	ROW Title Work & Survey Pemissions	90 days	Tue 1/18/22	Mon 5/23/22
9	Preliminary P & IDs	20 days	Tue 2/15/22	Mon 3/14/22
10	TIC Estimate and Schedule	20 days	Tue 3/15/22	Mon 4/11/22
11	Preliminary Survey	30 days	Sun 4/24/22	Mon 5/23/22
12	Environmental Survey for USACE Submittal	15 days	Fri 5/13/22	Thu 6/2/22
13	**Engineering, Procurement & Construction**	**400 days**	**Mon 1/2/23**	**Fri 7/12/24**
14	Project Kick Off	1 day	Mon 1/2/23	Mon 1/2/23
15	**Field Services**	**255 days**	**Tue 1/3/23**	**Mon 12/25/23**
16	Environmental Permitting	255 days	Tue 1/3/23	Mon 12/25/23
17	ROW Acquisition	195 days	Tue 1/3/23	Mon 10/2/23
18	**Pipeline Engineering**	**50 days**	**Tue 1/3/23**	**Mon 3/13/23**
19	Pipeline Engineering (Hydraulic Analysis)	25 days	Tue 1/3/23	Mon 2/6/23
20	Mapping/GIS (Routing)	50 days	Tue 1/3/23	Mon 3/13/23
21	**Facility Engineering**	**123 days**	**Tue 1/3/23**	**Thu 6/22/23**
22	Piping (PFD's, P&ID's, Plot Plans, BOM)	60 days	Tue 1/3/23	Mon 3/27/23
23	Mechanical (Pig L/R, Meter Skids, Booster Station)	80 days	Fri 2/3/23	Thu 5/25/23
24	Instrumentation and Electrical	40 days	Fri 4/28/23	Thu 6/22/23
25	Civil (Foundations, Civil Plot Plans)	30 days	Fri 5/12/23	Thu 6/22/23
26	**Long Lead Procurement**	**175 days**	**Fri 3/17/23**	**Thu 11/16/23**
27	Pipe Procurement	175 days	Fri 3/17/23	Thu 11/16/23
28	Valve Procurement	125 days	Fri 4/14/23	Thu 10/5/23
29	Booster Pumps	125 days	Fri 3/17/23	Thu 9/7/23
30	Pig L/R, Meter Skids	90 days	Fri 3/17/23	Thu 7/20/23
31	**Construction Bid Packages**	**105 days**	**Thu 6/22/23**	**Thu 11/16/23**
32	Issue for Bid	0 days	Thu 6/22/23	Thu 6/22/23
33	Construction Bidding Process	65 days	Fri 6/23/23	Thu 9/21/23
34	Construction Contract Award	40 days	Fri 9/22/23	Thu 11/16/23
35	**Construction**	**171 days**	**Fri 11/17/23**	**Fri 7/12/24**
36	Facilities Construction (Booster Station)	120 days	Fri 11/17/23	Thu 5/2/24
37	Pipeline Construction (including Mobilazation)	150 days	Fri 11/17/23	Thu 6/13/24
38	Start-Up and Commissioning	20 days	Fri 6/14/24	Thu 7/11/24
39	Ready for Service	1 day	Fri 7/12/24	Fri 7/12/24

Status Date : 3/5/2021
Printed Date : Tue 3/15/22 4:47 PM

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Critical
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Critical Split
Summary	Inactive Summary	Manual Summary	External Milestone	Progress
Manual Progress				

Appendix D



- PRELIMINARY -
NOT FOR CONSTRUCTION

REV	DESIGN BY	CHECKED BY	DATE
A	Issued for FEL-2 Report		
	S. Sunby	---	11-04-21

SVANTE

LAFARGE CO2 CAPTURE

Svante

Kiewit

PLOT PLAN

ENGINEER/DESIGN ORIGINATOR	S. Sunby
LEAD ENG	K. Satrom
ENG MGR	R. McLandsborough
PROJ MGR	N. Robinson

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Rapid Cycle Temperature Swing Adsorption Process Using Solid Structured Sorbent for CO_2 capture from Cement Flue Gas

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Abstract

Concrete is the most widely used man-made material in the world. The production process of cement, a key component of concrete, contributes significantly to CO_2 emissions. Every year, over 4 billion tonnes of cement are produced, releasing approximately 7%-8% of global CO_2 emissions [1]. Cement flue gas, processes and raw materials, contain around 16% CO_2 and 7-10% O_2 and NO_X /SO_X (100-300 ppm), contingent on the fuel type. High amounts of NO_X/SO_X are a significant challenge for any carbon capture system. The presence of high O_2 concentration in the emitted gas stream can chemically degrade typical amines via production of amides or other oxide derivatives. Therefore, it is crucial to conduct preliminary studies at a pilot scale using real cement flue gas conditions to develop a viable technology and accurate techno-economic analysis for large plants (1 million+ tonnes of captured CO2 per year).

Svante (formerly Inventys) has a strong patent portfolio on Rapid Cycle Temperature Swing Adsorption (RC-TSA) processes using structured adsorbents, steam-assisted direct regeneration with fast kinetics (< 1.5 mins cycle time) as an alternative to traditional liquid amine technologies. This project utilized scaled up CALF-20 sorbent, one of the first Metal Organic Frameworks (MOFs) used in an industrial CO_2 capture project. This MOF is robust with regards to steam, O_2 and acidic contaminant gases (such a NO_X/SO_X) which make it an ideal candidate for the cement CO_2 capture application.

This article discusses efforts to scale up the CALF-20 MOF sorbent from lab scale to ton scale. A review of CALF-20 performance after 2300 hrs of VeloxoTherm™ capture process results on a boiler flue gas doped with CO_2 and Air to simulate Cement kiln flue gas at 0.1 TPD capacity is presented. Also included are results from Phase 1 of the cement project related to NO_X/SO_X stability tests on CALF-20 sorbent.

Keywords: Svante, Cement, CO_2 capture, CO_2 utilisation, MOF, Rapid Cycle Temperature Swing Adsorption

1. Introduction

To meet the Paris Agreement 1.5°C target, emissions from industry will need to reach net zero around 2050. While power systems can be decarbonized with renewables and transportation systems can be decarbonized with fuel cells, hydrogen and electrification, emissions from industry face more significant challenges. Many industry emissions are a natural by-product of the manufacturing process itself. The cement industry, in particular, is both energy- and emissions-intensive due to the extreme heat required to produce cement from the combustion of fossil fuels and the release of CO_2 from the limestone during the process. Cement is the most widely used product after water, there are no easy substitute for construction of our modern cities. Approximately 60% of cement CO_2 emissions come from the limestone; thus, CO_2 capture is a solution to tackle 90% of emissions from a cement plant. If CO_2 capture is

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combined with biofuels or an integrated air capture system, the cement plant could even achieve negative emissions. Considering forecasted industry growth, cement manufacturing desperately needs a low-cost CO_2 capture solution. CO_2 results when calcium carbonate is thermally decomposed, producing lime and carbon dioxide [2] and when energy is used, particularly from combustion of fossil fuels. Depending on fuel types, the generated cement flue gas contains a high CO_2 concentration of 15-16%, a high O_2 content of 10-12%, and high concentration of NO_X/SO_X which could rapidly degrade amine-type solvents/sorbents. To improve the economics of the CO_2 capture process, it is vital to consider robust sorbents for cement's harsh flue gas conditions.

In 2009, Svante embarked on CO_2 capture technology development and created the VeloxoTherm™ process. The technology is based on intensified rapid cycle Temperature Swing Adsorption (RC-TSA) using a rotary machine to enable continuous flows (**Figure 1**). To operate a rapid cycle (<60 sec), increase productivity, and reduce plant footprint, Svante utilizes a structured adsorbent configuration with high specific area, low mass transfer and low pressure drop. As a result, fast gas transport/kinetics are achieved. Additionally, low pressure steam is used to heat the structured sorbent and desorb the CO_2 (direct heat) in seconds (<15 secs). Hence, steam stability of the sorbent structure is crucial for this technology.

This paper will present status report and results from a joint project, called CO_2MENT, between industries leader (Svante, Lafarge-Holcim, CCP (CO2 Capture Project from Chevron, BP and Petrobras) and TOTAL) to tackle all of the important steps to lead to large scale implementation; contaminants and particulates management, CO_2 capture and reuse as cement flue gas also approximates Fluid catalytic cracking (FCC) and Steam methane reformer (SMR) flue gases and the results have wider applicability for oil companies.

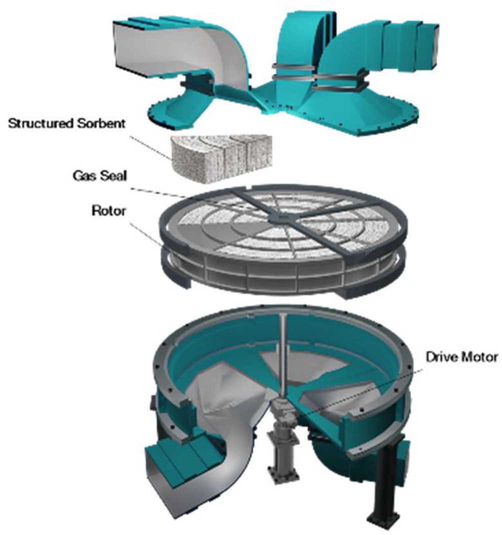

Figure 1: Typical VeloxoTherm™ compact Rotary Adsorption Machine (RAM) of Svante using structured solid sorbent

1.1. CO_2MENT Project

Project *CO_2MENT* will showcase Svante's CO_2 capture system and a selection of CO_2 utilization technologies at Lafarge's Richmond, British Columbia (BC), Canada cement plant over the next four years. This project, led by Svante, is a partnership with Lafarge Canada Inc., a member of the global building materials group, LafargeHolcim, CCP and TOTAL, all leading global energy companies.

The CO_2MENT project will tackle the main challenges of flue gas contaminants, CO_2 capture and CO_2 reuse. Svante will apply proprietary technology to generate innovative solutions for contaminant management and CO_2 capture (see **Figure 2**)

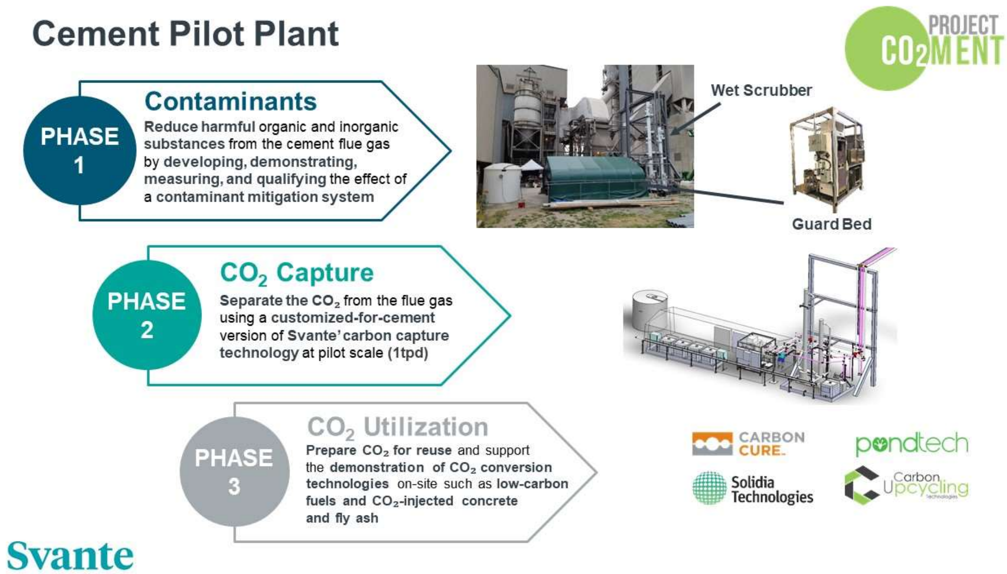

Figure 2 General Description of the three (3) phases of the CO2MENT *project*

Phase1: In Phase 1, started in November 2019, a combination of liquid scrubber and solid structured adsorbent are used to remove most of the NOx/SOx from the cement flue gas in order to protect the CO_2 adsorbent from possible poisoning.

Phase 2: In this phase, started in Q4 2020, Svante fabricated and installed a VeloxoTherm™ Rapid cycle TSA field testing unit (200 Series model) to capture 1 tonne of CO_2 per day from cement flue gas.

Phase 3: In this phase, expected to start in Q3 2021, industrial partners will use the capture CO_2 as a raw material for transformation into useful products such as injection into concrete, which is of prime importance when CO_2 is captured in a region where CO_2 storage is not viable or is limited.

Over the next four years, Project CO_2MENT will address all the important phases of CO_2 capture and utilization at the pilot plant scale using real flue gas, combining the efforts of world leading companies in this field.

2. Experimental

2.1 Phase 1 CO_2MENT Project Results

Phase 1 was completed in Q4-2019 with the installation of a kiln flue gas pre-treatment system to remove solid particulates, SO_x and NO_x impurities. In addition, it will be possible to control the amount of SOx, NOx and particulate that will be transferred to the CO_2 capture unit (Phase 2). The pre-treatment system consists of a Direct Contactor Cooler (DCC) using caustic scrubber and Svante's proprietary guard bed using activated carbon Structured Adsorbent Beds (SABs) (see Figure 3). The field trials demonstrated recovery of 90% of solid particles greater than 10 microns and the removal of SO_2 and NO_2 to less than 3 ppm and 1 ppm, respectively, in the flue gas entering the CO_2 capture system.

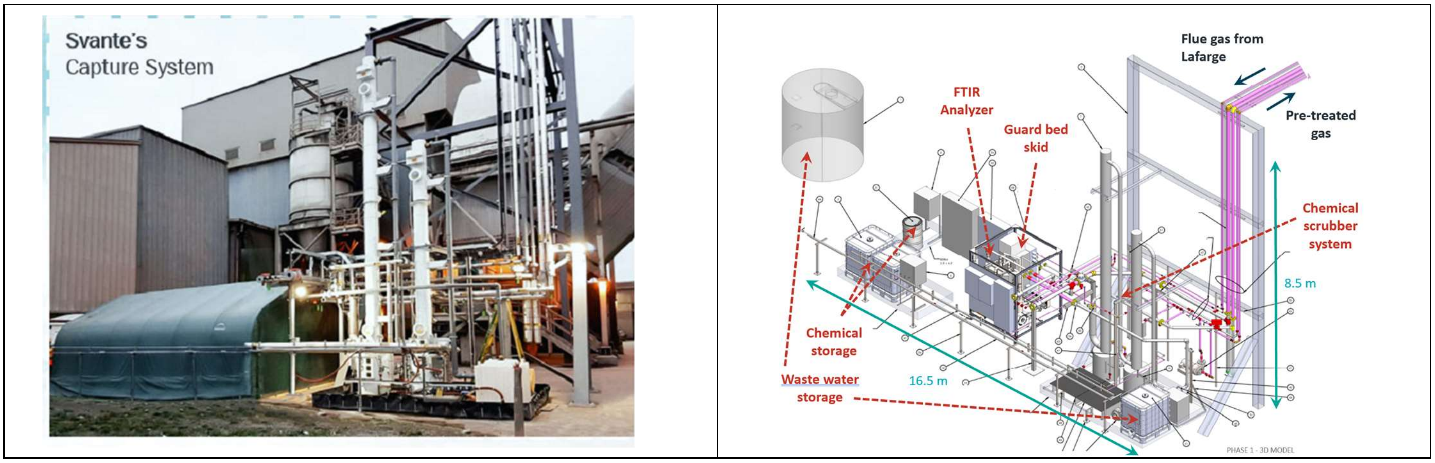

Figure 3: Tri-Mer system installed at the Lafarge Cement Plant in Richmond, BC (Phase 1)

2.1.1. Scrubbing system and flue gas contaminants

The objective of Phase 1 was to build and test a pre-conditioning plant to remove or control NOx and SOx before entering Svante's VeloxoTherm™ CO_2 Capture unit. The phase 1 plant includes a third-party (Tri-Mer) supplied scrubber unit to remove almost all SOx followed by a guard bed unit to remove almost most all NOx. The scrubber unit was designed to remove most of the entrained particles from the cement plant. The plant was started and tested during the period of November 2019 to March 2020.

<u>SO_X/NO_x Removal</u>

SO_2 in Lafarge flue gas (20-50 ppmv) was removed to below 3 ppm largely by a single stage scrubber without any chemical addition (caustic). Addition of Chemicals (e.g. NaOH) improved removal of SOx to <1.5 ppm and reduced waste water production. Figure 4 shows SO_2 removal with an operating pH of scrubber solution at around neutral (pH ~7). The amount of NO_2 was found higher after the scrubber which might be related to the NO to NO_2 conversion in the presence of water and oxygen in the flue gas (see Figure 4). At this condition, NaOH consumption was minimized and waste water production was reduced to a fraction of vendor design. It is also important to note that, in Figure 4, the fluctuation in flue gas composition including NOx and SOx could be attributed to the use of different mixture of various waste material and coal has a fuel source at this Lafarge Richmond Cement plant.

It was also noted that the amount of NO_2 was higher after the scrubber which might be related to the NO to NO_2 conversion in the presence of water and oxygen in the flue gas. At this condition, chemical consumption was minimized and waste water production was reduced to a fraction of vendor design.

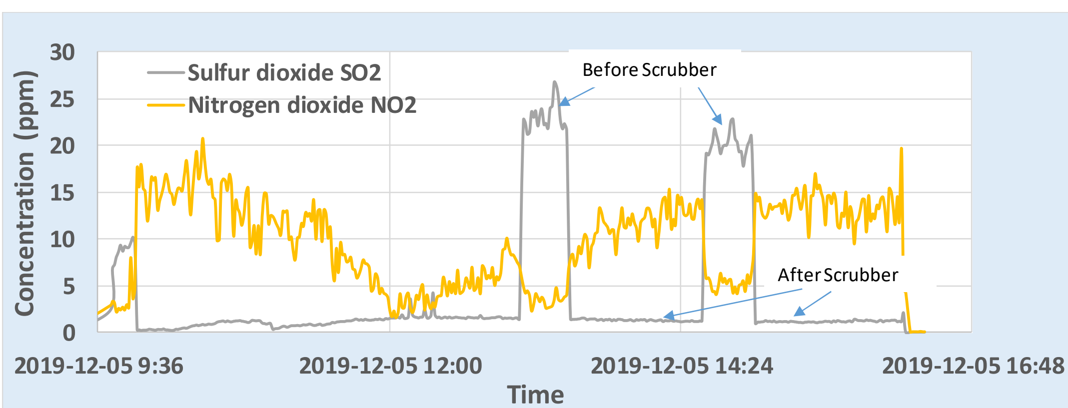

Figure 4 - SO2/NO2 removal at pH of ~7 by Tri-Mer scrubbers

The NO_2 reduction can be handled by a guard bed internally designed and built. The guard bed was able to completely remove the NO_2 passing through the scrubbers.

Particulate Removal

Total particle content in the flue gas was monitored and average of ~3.5 mg/m3 was detected during the 3-week testing period. After the Tri-Mer scrubber, the P10 particulate matter dropped to ~0.2 mg/m3, as shown in Figure 5. This represents more than 90% of reduction. It is also important to note that the size of the particulate (<10µm) is much lower than the channel height of the structure laminate, so no blockage is expected.

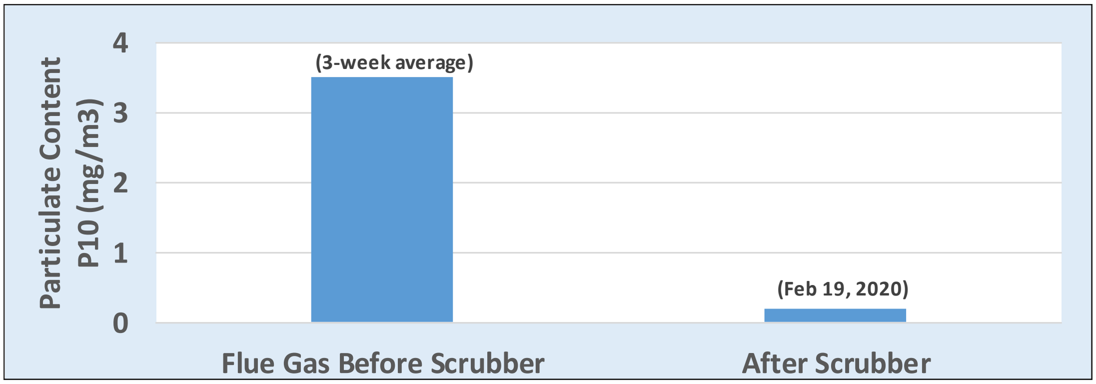

Figure 5- Particulate removal by Tri-Mer scrubbers

Proposed Pre-Treatment Scheme

Based on above results, a scrubber unit alone can serve as a DCC achieving both SOx removal and particulate matter reduction. Depending on NO_2 concentration in the feed and the sensibility of the carbon capture system used, a guard bed may be optional. Figure 6 is outlining the suggested configuration. Based on primary internal results of the stability of CALF-20 to SOx and NOx, we anticipate that a guard bed will not be necessary. This important point will be tested during phase 2 of this project.

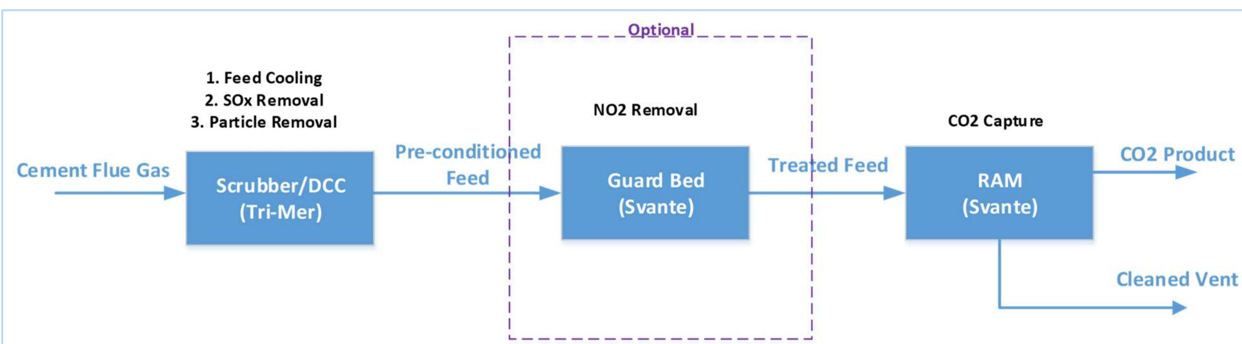

Figure 6 - SVT's pretreament system configuration

2.2. Phase 2 CO_2MENT Project Results

Phase 2 started in Q2 2020. Svante built the world's first VeloxoTherm™ 200 Series, able to capture up to 1 ton of CO_2 per day (TPD) using MOF material sorbent. Commissioning of this station was completed in January 2021. Operation with kiln flue gas is scheduled to start in February 2021 and to the best of our knowledge, it will be the world first field testing CO_2 capture demonstration unit to use MOF sorbent material. Figure 7 presents the plant overview and 3D layout of Phase 2 installed at the Lafarge Cement plant in Richmond BC.

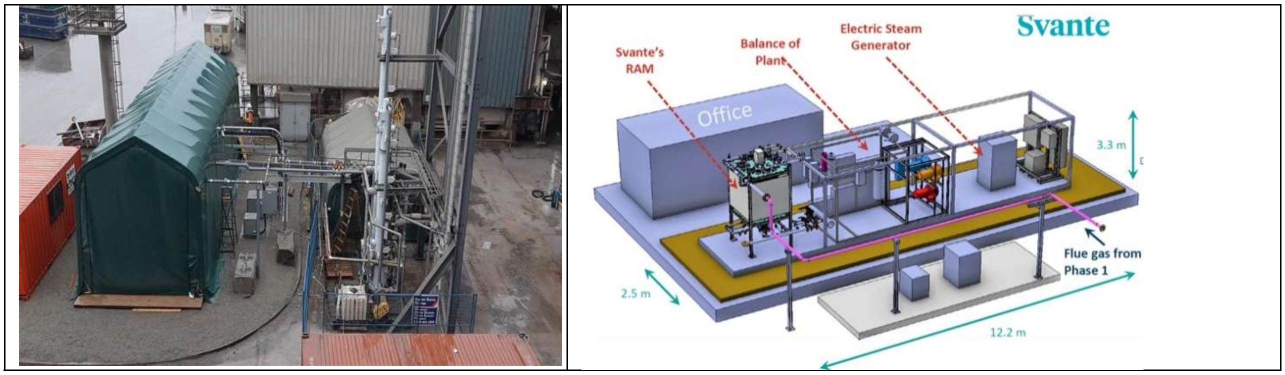

Figure 7: Picture of Svante's plant at Lafarge Cement Plant in Richmond BC, on the left, a picture of both Phase 1 and Phase 2. Image on the right is a 3D rendering of the Phase 2 plant based on Svante's RAM.

The next sections present the testing and the scale-up activities of the MOF sorbent that will be used in the Svante's RAM.

2.3. Svante's MOF sorbent

Svante sorbent portfolio incorporates a novel zinc-based sorbent metal organic framework (MOF) developed by Prof. G. Shimizu at University of Calgary (CALF-20) [3]. This novel MOF sorbent exhibits superior steam/water stability, and good stability to acidic gas contaminants such as NO_X/SO_X compared to amine-based solvents/sorbents. The use of a MOF material in a field-testing demonstration unit for point source carbon capture at this scale (~1 TPD) is a world first.

CALF-20 adsorbs CO_2 via a physisorption mechanism requiring lower energy for CO_2 desorption compared to chemically bonded amine-based sorbents (chemisorption). The advantages of this MOF material compared to other MOFs, are the selectivity of CO_2 over water at lower RH (<30%) and its very high stability to steam.

2.4. Svante sorbent's air stability

The stability of a sorbent is critical to reach the desired CO_2 capture cost because of the high O_2 content of the flue gas. It is difficult to impossible to add make-up sorbent during operations as can be done in a liquid amines absorption system. The sorbent lifetime needs to reach 3 to 5 years to be economically viable. Figure 8 presents results of accelerated oxidation testing using 110ºC dry air of one of Svante's amines sorbent and CALF-20 MOF. It is clearly shown that Svante's MOF is not prone to oxidation even up to 110ºC in the presence of dry air. However, as expected, Svante's amines sorbent displays a rapid decrease of activity when exposed at 110ºC air.

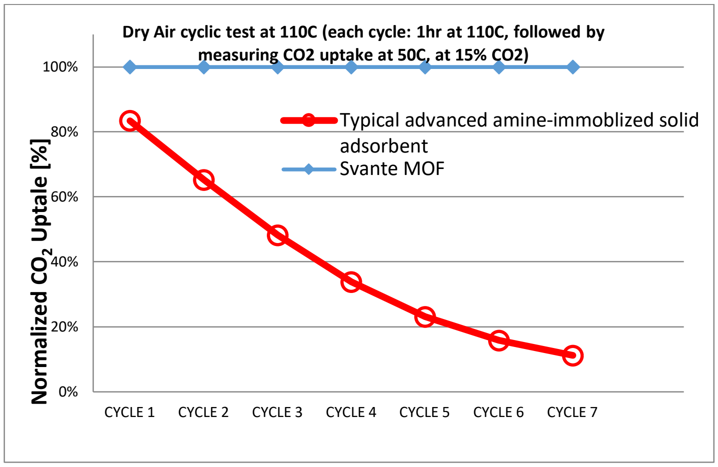

Figure 8: Accelerated oxidation testing at 110ºC under dry air (1 h /cycle). The capacity is measured in TGA using 15% CO2 (N2 balance) at 50ºC and normalized to the initial capacity. Blue and red data are showing, respectively, Svante CALF-20 MOF and Svante advanced amine-immobilized solid sorbent.

2.5. Svante's MOF structure sorbent's CO_2 adsorption performance (single bed)

Svante MOF material was coated on a substrate to form a laminate. All of the slurry and laminate processes or additives are carefully chosen in order not to decrease the CO_2 capacity of the sorbent material, keep the oxidation resistance and reach the necessary adhesion for the Veloxotherm™ process. Spacers are then added to create the gas channel between the laminated sheets that is stacked together to create a filter bed. The overall dimension of the filter bed tested is 2.5cm x 2.5cm x 100 cm. The bed is then tested in the VeloxoTherm™ Testing Station (VTS) replicating the complete cycle of the industrial rotary adsorption machine (RAM) in a batch process. The performance correlation between the VTS and RAM testing station is excellent (+/- 5% difference). The VTS is used to optimize all of the VeloxoTherm™ process.

Figure 9 is a picture of the VTS testing station. The temperature, pressure, gas compositions, and cycle timing can be changed on the fly to enable rapid testing and structures development. Analysis of the following parameters provides productivity metrics, which translate to system size: Product purity, CO_2 recovery and streams' flow rate/compositions and temperature.

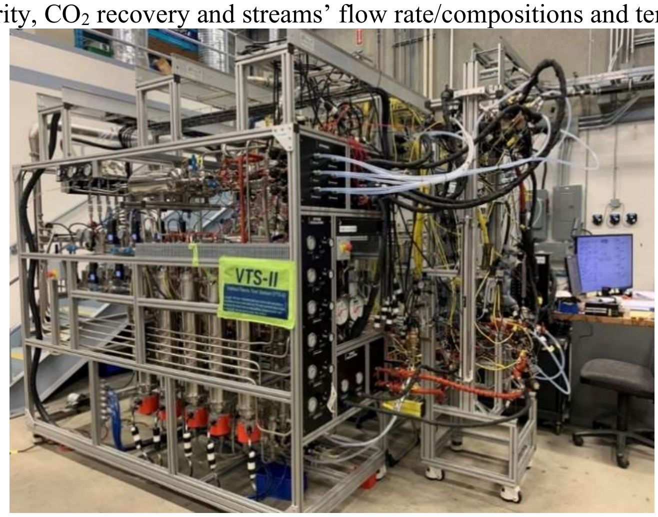

Figure 9: Svante VeloxoThermTM Test Station (or VTS)

Table 1 KPIs measured on CALF-20 on VTS (15.8% CO2, 4.8% Water, balance N2 in feed)

KPIs	Productivity [TPD/m^3]*	Steam Ratio (kg/kg)**	Total Cycle time [Sec]	Product Purity [%]
CALF-20	10.2	1.9 ±0.3	52	95

*Tonnes CO_2/m^3 bed. Day

** Amount of steam usage (kg)/amount of CO_2 produced (kg)

The KPIs presented in Table 1 are clearly showing the very good performance of the VeloxoTherm™ process using MOF material with a real flue gas composition. The addition of water in a cyclic condition (not only breakthrough) is essential for testing all sorbent material, especially the sorbent using physisorption. It is also important to note that those KPIs could be tuned with changing parameters in process to get required recovery or product purity. For example, some process optimization is now underway to decrease the steam ratio to a value as low as 1.5.

2.6. Svante's MOF structure sorbent process stability

Long-term laboratory testing of the VeloxoTherm™ process at the scale of 0.1 TPD using the new CALF-20 MOF Structured Adsorbent Beds (SABs) has been underway since Q1-2020 with outstanding stability using a simulated kiln flue gas in a PDU (Process Demonstration Unit). The PDU is a rotational adsorption machine (RAM) mimicking the VeloxoTherm™ technology at smaller scale (Figure 10). This PDU laboratory testing station contains 8 sorbent beds of CALF-20 with a total of 0.1 TPD CO_2 capture capacity.

For simulating cement flue gas, generated flue gas from a natural gas boiler was enriched with pure CO_2 and air to adjust both CO_2 and O_2 concentrations similar to cement kiln flue gas composition (17% CO_2, 10% O_2, 5% H_2O, Balanced N_2). The gas analyser recorded around 60 ppm NO and 12 ppm NO_2 in the generated flue gas.

Two series of beds were prepared and tested in the PDU; Set 1 beds having lower permeability than 6000 Darcy (higher pressure drop), for stability testing of CALF-20, and Set 2 beds having higher permeability than 6000 Darcy (lower pressure drop) for performance testing. Both series are using the same CALF-20 synthesis methods, only bed permeability was changed.

During the first 2000 hrs of process testing on Set 1 beds, the flue gas passed through the guard bed, an activated carbon structured bed to scrub NO_X. After 2000 hrs of process the flue gas bypassed the guard bed flowed directly through the beds to check the effect of NO_X on bed durability on process performances for 220hr. Figure 11 confirms no change in the stability even when 12 ppm of NO_2 was injected in the bed (without guard bed operation).

Figure 10: Process Demonstration Unit (PDU) at 0.1 TPD CO2 capture capacity

Figure 11 shows the Key Performance Indicators (KPIs) changing trend, productivity, product purity and steam ratio SR over 2300 hr continuous process test on the PDU using simulated cement kiln flue gas. CALF-20 clearly demonstrates superior performance stability after 2000 hr test (over 120,000 cycles) displaying no significant physical/chemical degradation under direct steam exposure, oxygen in flue gas, or hot air as a conditioning step. To the best of our knowledge, this is the first ultra-stable MOF tested for post-combustion carbon capture at industrial flue gas scale using direct steam-assisted regeneration.

Figure 11: KPIs change trend of PDU over 2000hr process testing under simulated cement flue gas

To fully evaluate the performance of CALF-20 using the VeloxoTherm™ cycle, beds with higher permeability (lower pressure drop, Set 2) were used. These new beds use the same batch of CALF-20 materials. Higher permeability beds are necessary to better dry the beds during the cooling step and increase the CO_2 capacity of this MOF material. Set 2 beds were installed on the same PDU with the cycle optimized to 55 sec (1.1 cpm). The results over 100 hr continuous testing are in Figure 12 confirming a steam ratio between 2.0 to 2.2, productivity of 8.0 to 9.5 TPD/m3 depending on recovery/capture efficiency and product purity of 85% to 95% achievable depending on cycle tuning.

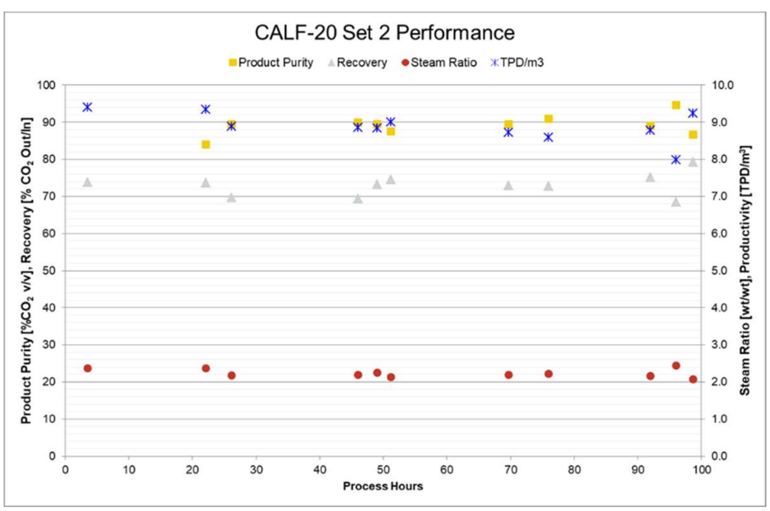

Figure 12: KPIs trend of PDU over 2000hr process testing under simulated cement flue gas

2.7. CALF-20 MOF sorbent scale up

Scalability and low cost of a solid sorbent are essential since the amount needed for a typical cement flue gas capture plant (4,500 tonnes CO_2 per day) will be in the range of 200 tonnes. Large scale production of MOF materials at low cost is a daunting task but necessary to make this technology viable. Every step of the process, from the selection of all the raw materials to the synthesis procedure must be carefully designed to meet that goal. CALF-20 was engineered from the ground up to be stable in flue gas CO_2 capture conditions and easily scalable. CALF-20 sorbent was first produced in a 300 g batch size in “one pot” using research-grade high quality raw ingredients. Zinc carbonate basic, 1,2.4-Triazole and Oxalic acid dehydrate were mixed into Methanol/water mixture at RT conditions. The precipitated colorless powder was filtered and washed only with water followed by drying in oven at 110ºC overnight. The XRD spectrum confirmed pure CALF-20 phase in product. TGA data showed 43-45 cc/g CO2 uptake at 50ºC, 15% CO_2/balance He. Before the CO_2 measurement, the sample was regenerated at 110ºC under He gas on TGA. The gas flowrate set at 200 ml/min on TGA for both inert gas and active gas in Q500 TGA instrument.

After successful scale up to 300g/batch, the next step was to scale up to 4-5 kg batch size using low-cost commercial grade raw ingredients. For this, a 20L jacketed reactor with a strong agitator was used. The synthesis process was repeated similar to the 300g batch process, with the same mole ratio of ingredients into Methanol/water. After reaction completion, the product was washed/filtered and dried in an oven. The final powder showed the same XRD and CO_2 uptake on TGA as the 300g batch.

Finally, the CALF-20 synthesis package was transferred to the world-renowned MOF manufacturer, BASF, to continue the scale-up to tonnes scale production. CALF-20 was scaled up successfully to 300 kg batch in Q4-2020 and BASF produced more than 1 tonne of CALF-20. Table 2 is comparing the CO_2 capacity of different scale-up materials compared to Svante’s standard. All of the scale-up batches (25 kg and 300 kg) are all showing in specs CO_2 capacity at both 50ºC and 110ºC. This clearly showing a very good reproducibility robustness in the scale-up.

Table 2 TGA capacity of Svante reference material and scale-up materials at different batch size and batch number

Trial	**Capacity (cc/g) @ 15% CO_2 in He**	
	50°C	**110°C**
Svante reference	**43±3**	**7±1**
25kg #1	45.1	7.9
25kg #2	44.9	8
25kg #3	45.2	8.1
300kg #1	43.1	7.6
300kg #2	45.3	8
300kg #3	43.5	7.8

2.8. Phase 3 CO_2MENT Project Update

Phase 3 will begin in Q3 2021 and will demonstrate utilization technologies where CO_2 is permanently sequestered into concrete. Solidia, a leading US based utilization company, will use Svante captured CO_2 to cure concrete in a pre-cast plant next door. CarbonCure will use Svante captured CO_2 to cure and strengthen ready mix concrete in a plant onsite. Carbon Upcycling will use Svante captured CO_2 to inject into fly-ash for use in concrete production.

3. Next Phase

LafargeHolcim, Svante's project partner operates over 270 cement plants worldwide representing CO_2 emissions of >300 million tonnes per year. LafargeHolcim's CO_2MENT Colorado project received $1.5 million from the United States Department of Energy's (DOE) National Energy Technology Laboratory. The project is a collaboration with Svante, Oxy Low Carbon Ventures, a wholly-owned subsidiary of Occidental and Total. The funding will allow the partnership to evaluate the feasibility of the facility, designed to capture up to 1.5 million tonnes of carbon dioxide per year from the cement plant and the natural gas-fired steam generator. The captured carbon dioxide will be sequestered underground permanently by Occidental.

Conclusion

Rapid Cycle Thermal Swing CO_2 adsorption using Metal Organic Framework (MOF) solid sorbent for point source carbon capture of hard-to-abate industrial sources of CO_2, like cement and blue hydrogen is very promising. This CO_2MENT Richmond project combining industries leader (Svante, Lafarge-Holcim, CCP (CO2 Capture Project from Chevron, BP and Petrobras) and TOTAL) will use a field -testing demonstration unit to acquire all of the necessary data needed for the implementation at large commercial scale in the CO_2MENT Colorado project.

This work clearly showed the stability of the CALF20 sorbent material to fast thermal swing using direct steam, superior stability to oxidation and NOx. This material was scaled-up with excellent yield (> 90%) and high Space Time Yield for precipitation (STY ~ 550 kg/m3d). At high volume this material has the potential to reach the target cost needed for low-cost carbon capture. This is an important accomplishment for this class of sorbent material to be used in economically viable CO_2 capture process.

Acknowledgments

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References

[1] https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete

[2] EIA report– Emissions of Greenhouse Gases in the U.S. 2006-Carbon Dioxide Emissions

[3] US Patent US 9782745 B2, "Metal organic framework, production and use thereof"

LafargeHolcim Equipment List

Equipment Tag	Svante Tag	Equipment Description	P&ID
1Z-LPS-BLR-01/02/03	HB-1801	LOW PRESSURE BOILERS	PD-040
1A/B/C/D-RAM-RAM-01	VM-20(0/1/2/3)1	RAM	PD-041, PD-042, PD-161, PD-180, PD-202, PD-211
1Z-LPS-DEA-01	N/A	DEAERATOR	PD-043
1Z-LPS-PMP-01A/B/C	N/A	BOILER FEED PUMPS	PD-043
1Z-CND-PMP-01A/B	P-0501	FLUE GAS DCC CONDENSATE PUMP	PD-050
1Z-CND-PMP-02A/B	P-0101	CONDITIONING 1 DCC CONDENSATE PUMP	PD-050
1Z-CND-HEX-02	EA-3202	CONDITIONING 1 DCC CONDENSATE COOLER	PD-050
1Z-CND-PMP-03A/B	P-31(0/1)3	REFLUX CONDENSATE PUMP	PD-051
1Z-CND-PMP-04A/B	P-31(2/3)3	REFLUX CONDENSATE PUMP	PD-051
1Z-CND-PMP-05A/B	P-3101	PRODUCT CONDENSATE PUMP	PD-052
1Z-CND-PMP-06	P-3102	PRODUCT CONDENSATE PUMP	PD-052
1Z-CND-TNK-01	T-3101	CONDENSATE TANK	PD-053
1Z-CND-PMP-07	P-3104	CONDENSATE TRANSFER PUMP	PD-053
1Z-CND-HEX-01	EW-3201	FLUE GAS DCC CONDENSATE HEAT EXCHANGER	PD-054
1Z-CND-SMP-01	N/A	FLUE GAS CONDENSATE SUMP	PD-055
1Z-CND-PMP-018A/B	N/A	FLUE GAS CONDENSATE SUMP PUMP	PD-055
1Z-BDN-PMP-01A/B	N/A	HOT DRAINS SUMP PUMP	PD-090
1Z-BDN-SMP-01	N/A	HOT DRAINS SUMP	PD-090
1Z-CAS-BLW-01	BL-0101	CONDITIONING AIR BLOWER	PD-160
1Z-CAS-HTR-01	EC-0101	CONDITIONING 1 HEATER	PD-160
1Z-CAS-HTR-02	EC-0201	CONDITIONING 2 HEATER	PD-160
1Z-CAS-FLT-01	N/A	CONDITIONING AIR INLET FILTER	PD-160
1Z-CAS-FSP-01	VC-0101	DIRECT CONTACT COOLER	PD-162
1Z-PGS-FSP-01A/B	V-1101/1102	PRODUCT SEPARATOR	PD-181
1Z-PGS-BLW-01	BL-1101	PRODUCT BLOWER	PD-181
1Z-PGS-HEX-05	ES-1102	PRODUCT CW COOLER	PD-181
1Z-PGS-CMP-01	K-1201	PRODUCT COMPRESSOR	PD-182, PD-184
1Z-PGS-FSP-04	V-1204	POST ORU SEPARATOR	PD-183
1Z-PGS-HEX-07	EP-1202	REACTOR EFFLUENT TRIM COOLER	PD-183
1Z-PGS-HEX-08	EP-1201	REACTOR FEED/EFFLUENT EXCHANGER	PD-183
1Z-PGS-FSP-07	R-1201	OXIDATION REACTOR PT CATALYST	PD-183
1Z-PGS-HTR-01	HE-1201	REACTOR TRIM HEATER	PD-183
1Z-RGS-BLW-01A/B	BL-08(0/1)1	REFLUX BLOWER	PD-200
1Z-RGS-HEX-01	EP-08(0/1)1	REFLUX COOLER	PD-200
1Z-RGS-FSP-01	V-08(0/1)1	REFLUX MOISTURE SEPARATOR	PD-200
1Z-RGS-BLW-02A/B	BL-08(2/3)1	REFLUX BLOWER	PD-201
1Z-RGS-HEX-02	EP-08(2/3)1	REFLUX COOLER	PD-201
1Z-RGS-FSP-02	V-08(2/3)1	REFLUX MOISTURE SEPARATOR	PD-201
1Z-FLG-FSP-01	VC-0501	DIRECT CONTACT COOLER	PD-210
1Z-FLG-BLW-01	BL-0401	FLUE GAS BLOWER	PD-210
1Z-FLG-SKD-01	N/A	MAIN DUCT DAMPER SEAL AIR SKID	PD-210
1Z-FLG-STK-01	FS-3601	VENT STACK	PD-212
1Z-FLG-CEM-01	N/A	CEMS ENCLOSURE	PD-212
1Z-TEG-HEX-01	EP-1203	TEG HEAT EXCHANGER	PD-220
1Z-TEG-TNK-01	N/A	TEG STORAGE TANK	PD-220
1Z-TEG-TWR-01	N/A	TRIETHYLENE GLYCOL TOWER	PD-220
1Z-TEG-SKD-01	N/A	TRIETHYLENE GLYCOL REGENERATION SKID	PD-220
1Z-TEG-SMP-01	N/A	TEG CONTAINMENT SUMP	PD-220
1Z-CWS-PMP-01A/B/C	P-3301	CIRCULATING WATER PUMP	PD-260
1Z-CWS-PMP-02	N/A	AUXILIARY CIRCULATING WATER PUMP	PD-260
1Z-PGS-HEX-01	EA-1201/2/3/4/5	COMPRESSOR COOLER	PD-264
1Z-CWS-CTW-01	ET-3301	COOLING TOWER	PD-265
1Z-CWS-FAN-01/02/03/04/05/06/07/08	N/A	COOLING TOWER FAN	PD-265, PD-266, PD-267
1Z-FLG-HEX-01	N/A	FLUE GAS BLOWER LUBE OIL HEAT EXCHANGER	PD-268
1Z-RGS-HEX-03	N/A	REFLUX BLOWER LUBE OIL HEAT EXCHANGER	PD-268
1Z-RGS-HEX-04	N/A	REFLUX BLOWER LUBE OIL HEAT EXCHANGER	PD-268
1Z-CAS-HEX-01	N/A	CONDITIONING AIR BLOWER LUBE OIL HEAT EXCHANGER	PD-269
1Z-PGS-HEX-02	N/A	PRODUCT BLOWER LUBE OIL HEAT EXCHANGER	PD-269
1Z-RWS-STR-01A/B/C	N/A	RIVER INTAKE SCREEN	PD-360
1Z-RWS-BLD-01	N/A	INTAKE STRUCTURE	PD-360
1Z-RWS-PMP-01A/B	N/A	RAW WATER INTAKE PUMP	PD-360
1Z-RWS-CMP-01A/B	N/A	AIR COMPRESSOR	PD-361
1Z-RWS-REC-01	N/A	WET AIR RECEIVER	PD-361
1Z-DWT-ENC-01	N/A	DEMINERALIZED WATER TREATMENT TRAILER	PD-375
1Z-DWT-ENC-02	N/A	DEMINERALIZED WATER TREATMENT TRAILER	PD-375
1Z-DWT-ENC-03	N/A	DEMINERALIZED WATER TREATMENT TRAILER	PD-375
1Z-DWT-ENC-04	N/A	CONDENSATE TREATMENT TRAILER	PD-376
1Z-DWT-ENC-05	N/A	CONDENSATE TREATMENT TRAILER	PD-376
1Z-DWT-ENC-06	N/A	CONDENSATE TREATMENT TRAILER	PD-376
1Z-DWT-ENC-07	N/A	CONDENSATE TREATMENT TRAILER	PD-376
1Z-SWS-TNK-01	N/A	SERVICE/FIRE WATER TANK	PD-390
1Z-SWS-HTR-01A/B	N/A	SERVICE/FIRE WATER TANK HEATER	PD-390
1Z-SWS-PMP-01A/B	N/A	SERVICE WATER PUMP	PD-391
1Z-SWS-SKD-01	N/A	SERVICE WATER PUMP SKID	PD-391
1Z-SWS-PMP-02A/B	N/A	SODIUM HYPOCHLORITE FEED PUMP	PD-393
1Z-SWS-TNK-02	N/A	SODIUM HYPOCHLORITE STORAGE TOTE	PD-393
1Z-SWS-SKD-02	N/A	SODIUM HYPOCHLORITE FEED PUMP SKID	PD-393

Equipment Tag	Svante Tag	Equipment Description	P&ID
1Z-PWS-SKD-01	N/A	POTABLE WATER TEMPERING SKID	PD-400
1Z-PWS-PMP-01A/B	N/A	POTABLE WATER PUMP	PD-400
1Z-DWS-TNK-01	N/A	DEMINERALIZED WATER STORAGE TANK	PD-410
1Z-DWS-HTR-01	N/A	DEMINERALIZED WATER TANK HEATER	PD-410
1Z-DWS-PMP-01A/B	P-1901	DEMINERALIZED WATER FORWARDING PUMP	PD-411
1Z-DWS-SKD-01	N/A	DEMINERALIZED WATER FORWARDING PUMP SKID	PD-411
1Z-WWT-TNK-10	N/A	EQUALIZATION TANK	PD-420
1Z-WWT-CLF-01A/B	N/A	SOFTENING CLARIFIER	PD-420
1Z-WWT-TNK-13	N/A	CLEARWELL TANK	PD-420
1Z-WWT-SKD-14	N/A	CLEARWELL FORWARDING PUMP SKID	PD-421
1Z-WWT-PMP-14A/B	N/A	CLEARWELL FORWARDING PUMPS	PD-421
1Z-WWT-TCK-01	N/A	THICKENER	PD-425
1Z-WWT-SKD-22	N/A	CLARIFIER SLUDGE SKID PUMP SKID	PD-425
1Z-WWT-PMP-22A/B	N/A	CLARIFIER SLUDGE PUMP	PD-425
1Z-WWT-SKD-23	N/A	PRESS FILTER FEED PUMP SKID	PD-425
1Z-WWT-PMP-23A/B	N/A	PRESS FILTER FEED PUMP	PD-425
1Z-WWT-FLT-01A/B	N/A	BELT FILTER/ PRESS FILTER	PD-425
1Z-WWT-MXR-03	N/A	THICKENER RAKE	PD-425
1Z-WWT-SLO-01	N/A	LIME STORAGE SILO	PD-426
1Z-WWT-TNK-01	N/A	LIME SLURRY TANK	PD-426
1Z-WWT-PMP-01A/B/C	N/A	LIME FEED PUMP	PD-426
1Z-WWT-SLO-02	N/A	SODA ASH STORAGE SILO	PD-426
1Z-WWT-TNK-02	N/A	SODA ASH SLURRY TANK	PD-426
1Z-WWT-PMP-02A/B/C	N/A	SODA ASH FEED PUMP	PD-426
1Z-WWT-SKD-09	N/A	LIME FEED PUMP SKID	PD-426
1Z-WWT-SYS-01	N/A	LIME STORAGE SYSTEM	PD-426
1Z-WWT-SYS-02	N/A	SODA ASH STORAGE SYSTEM	PD-426
1Z-WWT-SKD-02	N/A	SODA ASH FEED SKID	PD-426
1Z-WWT-TNK-03	N/A	COAGULANT STORAGE TANK	PD-427
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1Z-WWT-PMP-04A/B	N/A	SULFURIC ACID FEED PUMP	PD-427
1Z-WWT-DES-01	N/A	DESSICANT VENT DRYER	PD-427
1Z-WWT-TNK-05	N/A	CLARIFIER POLYMER STORAGE TOTE	PD-428
1Z-WWT-SKD-05	N/A	CLARIFIER POLYMER FEED PUMP SKID	PD-428
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1Z-WWT-PMP-06A/B	N/A	THICKENER POLYMER FEED PUMP	PD-428
1Z-WWT-TNK-07	N/A	PRESS FILTER POLYMER STORAGE TOTE	PD-428
1Z-WWT-SKD-07	N/A	PRESS FILTER POLYMER FEED PUMP SKID	PD-428
1Z-WWT-PMP-07A/B/C	N/A	PRESS FILTER POLYMER FEED PUMP	PD-428
1Z-WWT-SMP-17	N/A	OVERFLOW SUMP	PD-432
1Z-WWT-PMP-17A/B	N/A	OVERFLOW SUMP PUMP	PD-432
1Z-WWT-MXR-02	N/A	OVERFLOW SUMP MIXER	PD-432
1Z-WWT-MXR-01A/B	N/A	SOFTENING CLARIFIERS MIXERS	PD-420
1Z-FPS-PMP-01	N/A	ELECTRIC FIRE PUMP	PD-470
1Z-FPS-PMP-02	N/A	JOCKEY FIRE PUMP	PD-470
1Z-FPS-PMP-03	N/A	DIESEL FIRE PUMP	PD-470
1Z-FPS-ENC-01	N/A	FIRE PUMP EMCLOSURE	PD-470
1Z-SMP-ENC-01	N/A	SAMPLE PANEL ENCLOSURE	PD-500
1Z-SMP-PNL-01	N/A	SAMPLE PANEL	PD-500
1Z-SMP-PNL-02	N/A	CIRCULATING WATER SAMPLE PANEL	PD-501
1Z-SMP-PNL-03	N/A	COOLING TOWER BLOWDOWN SAMPLE PANEL	PD-501
1Z-CCF-PMP-01A/B	N/A	LP BOILER AQUEOUS AMMONIA FEED PUMP	PD-520
1Z-CCF-TNK-01	N/A	AQUEOUS AMMONIA TOTE	PD-520
1Z-CCF-SKD-01	N/A	LP BOILER AQUEOUS AMMONIA FEED PUMP SKID	PD-520
1Z-TCF-TNK-01	N/A	COOLING TOWER SODIUM BISULFITE STORAGE TOTE	PD-530
1Z-TCF-SKD-01	N/A	COOLING TOWER SODIUM BISULFITE FEED PUMP SKID	PD-530
1Z-TCF-PMP-01A/B	N/A	COOLING TOWER SODIUM BISULFITE FEED PUMP	PD-530
1Z-TCF-DES-01	N/A	DESICCANT VENT DRYER	PD-530
1Z-TCF-TNK-02	N/A	COOLING TOWER SULFURIC ACID STORAGE TANK	PD-530
1Z-TCF-SKD-02	N/A	COOLING TOWER SULFURIC ACID PUMP SKID	PD-530
1Z-TCF-PMP-02A/B	N/A	COOLING TOWER SULFURIC ACID FEED PUMP	PD-530
1Z-TCF-TNK-03	N/A	COOLING TOWER SODIUM HYPOCHLORITE STORAGE TANK	PD-531
1Z-TCF-SKD-03	N/A	COOLING TOWER SODIUM HYPOCHLORITE FEED PUMP SKID	PD-531
1Z-TCF-PMP-03A/B	N/A	COOLING TOWER SODIUM HYPOCHLORITE FEED PUMP	PD-531
1Z-TCF-TNK-04	N/A	COMBINATION PRODUCT STORAGE TOTE	PD-531
1Z-TCF-SKD-04	N/A	COMBINATION PRODUCT FEED PUMP SKID	PD-531
1Z-TCF-PMP-04A/B	N/A	COMBINATION PRODUCT FEED PUMP	PD-531
1Z-INA-CMP-01A/B	N/A	AIR COMPRESSOR	PD-560
1Z-INA-FLT-01	N/A	AIR PRE-FILTER	PD-560
1Z-INA-REC-01	N/A	WET AIR RECEIVER	PD-560
1Z-INA-ADY-01A/B	N/A	AIR DRYER	PD-561
1Z-INA-FLT-02	N/A	AIR AFTER FILTER	PD-561
1Z-INA-REC-02	N/A	DRY AIR RECEIVER	PD-561
1Z-CMG-SKD-01	N/A	NITROGEN BOTTLE MANIFOLD	PD-570
1Z-HYG-SKD-01A/B	N/A	HYDROGEN GENERATION SKID	PD-580

Equipment Tag	Svante Tag	Equipment Description	P&ID
1Z-HYG-TNK-01	N/A	HYDROGEN BUFFER TANK	PD-580
1Z-FGS-SKD-01	N/A	LP FUEL GAS REGULATING SKID	PD-650
1Z-SDR-TNK-01	N/A	SANITARY WASTE HOLDING TANK	PD-950
1Z-WDR-PMP-01A/B	N/A	OIL/WATER SEPARATOR SUMP PUMP	PD-960
1Z-WDR-SEP-01	N/A	OIL/WATER SEPARATOR	PD-960
1Z-WDR-SMP-01	N/A	WASTEWATER COLLECTION SUMP	PD-961
1Z-WDR-PMP-02A/B	N/A	WASTEWATER COLLECTION SUMP PUMP	PD-961
1Z-WDR-SKD-01	N/A	COMPOSITE SAMPLER	PD-961


Holcim Carbon Capture Facility Site Plan
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TP-#6, #8, #9
TP-7
TP-10
120
112
LafargeHolcim Portland
Arkansas River
Tie in Point List
TP-1 Flue Gas From Cement Plant
TP-2 River Water Intake
TP-3 Fuel Gas From Pipeline
TP-4/5 NOT USED
TP-6 Raw Water From Cement Plant
TP-7 115 KV line into switchyard
TP-8 Potable Water From Cement Plant
TP-9 Wastewater Discharge to Cement Plant
TP-10 Product CO2 Gas Stream
N
1000 ft
Google Earth

PERMIT MATRIX

LafargeHolcim CO2MENT Project

TYPICAL FEDERAL AND STATE PERMITS REQUIRED FOR PIPELINE IN COLORADO

Note: This is a typical permit matrix for a pipeline in Colorado. Actual permit requirements will be decided after the selection of the pipeline route.

Agency	Permit	Notes	Duration
Federal			
USACE	Permit - Section 404 of the CWA Permit - Section 10 of the Rivers & Harbors Act	Anticipated coverage under NWP 12 assuming compliance with NWP performance standards and Regional conditions. PCN required if: •A section 10 permit is required •Mechanized land clearing in forested wetlands for the ROW •Discharge results in the loss of >1/10 acre If NWP and regional conditions cannot be met then an IP may be required	Nationwide Permits – 4 to 6 months Individual – 10-12 months
USFWS	Consultation - Section 7 Endangered Species Act (ESA) Consultation - MBTA and BGEPA	Potential impacts on federally-listed T&E species, protected eagles, and migratory birds. If Project may result in a "take," USFWS may prepare Biological Opinion (BO) in consultation with the FERC	One month (30 to 45 days for clearance) 6 months (minimum) if Biological Opinion required
U.S. Environmental Protection Agency (EPA)	Prevention of Significant Deterioration Permit (PSD) – Air Air Operating (Title V) Permit		TBD
EPA	Spill Prevention, Control, and Countermeasures Plan	Need to have Spill Prevention, Control and Countermeasure plan on site during construction	3 months
EPA	NPDES Permit	Need to have SWP3 on site during construction	1 month to prepare Online registration
State			
Colorado Dept. of Public Health and Environment	COR400000 - Stormwater Discharge from Construction Activities	Federal NPDES permit administered by the state of Colorado	10 days from receipt of complete application
Colorado Dept. of Public Health and Environment	COG604000 - Hydrostatic Test Water Discharge		10 days from receipt of complete application
Colorado Dept. of Public Health and Environment	401 Water Quality Certification		Concurrent with USACE 404 authorization 60 to 120 days from receipt of complete application
Colorado Dept. of Public Health and Environment	Air Pollutant Emission Notice or General Permit	TBD	TBD
Colorado Oil and Gas Conservation Commission	Form 2A - Oil and Gas Location Assessment	If project is associated with oil and gas development operations	21 days from receipt of complete form
Colorado State Historic Preservation Office	Section 106 Review/Consultation	Federal authorization administered by the state of Colorado	60 - 90 days from receipt of Cultural Resources Investigation Report
County (Counties through which the pipeline passes)	Floodplain Development Permit	If necessary, could be a waiver or not required depending on scope and/or applicability of below ground installations	TBD
Colorado Natural Heritage Program	Consultation	Not a permitting authority, additional level of review to support federal authorizations via USACE and USFWS	Concurrent with USACE 404 authorization 60 to 120 days from receipt of complete application

AREA MAP FOR HOLCIM, CO -
4750 TPD CO2 CAPTURE - CEMENT PLANT

Appendix I-1

AREA 1: RAM
- RAM Components, gear drive, RAM electrical & control panels
- RAM Foundation,
- RAM Structural Steel, RAM Platforms
- Other direct RAM items

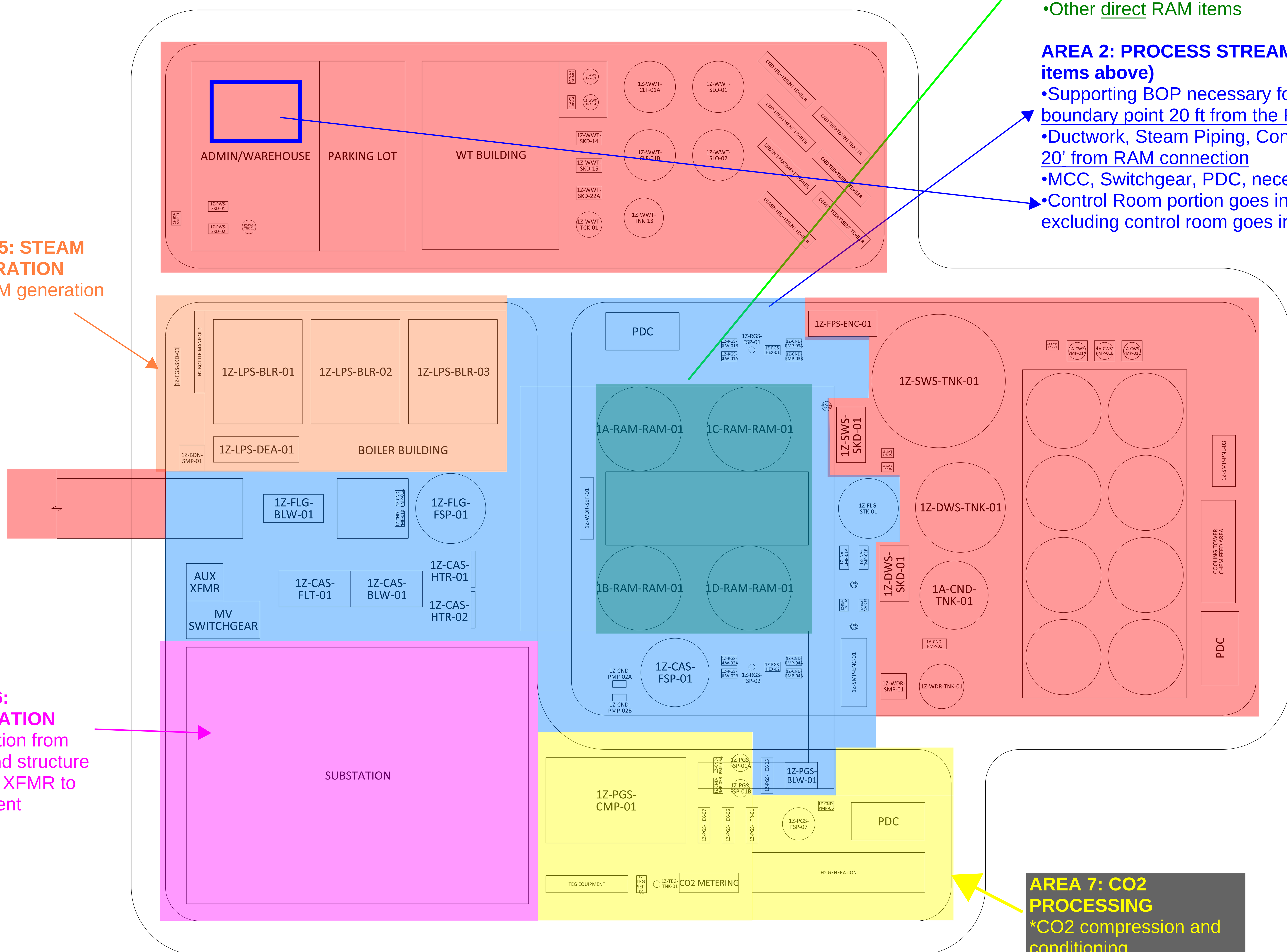
AREA 2: PROCESS STREAM BOP (excludes cost bucket #1 RAM items above)
- Supporting BOP necessary for the RAM to function – taken to a boundary point 20 ft from the RAM
- Ductwork, Steam Piping, Conditioning Air, Utilities, Supports - out to 20' from RAM connection
- MCC, Switchgear, PDC, necessary to make the Capture Plant run
- Control Room portion goes into this cost bucket. Admin building excluding control room goes into cost bucket 4.

AREA 5: STEAM GENERATION
*STEAM generation

AREA 3: ADDITIONAL SITE BOP (BOP that is unique and required due to the specific site location or client requirements)
- Additional Ductwork, Steam Piping, Conditioning Air, Supports, Utilities (gas, water, air, electrical) – from 20' to actual connection. (Example: the 980' of flue gas ductwork and support steel to get from the RAM boundary over to the connection point at the cement plant)
- Water Treatment
- Tanks
- Cooling Tower
- Fire Protection, loops and equipment

AREA 4: SITE INFRASTRUCTURE:
- Earthworks (cut/fill)
- Piles (if required)
- Roads, Drainage,
- Improvements (fences, security, lighting)
- Admin Building/Warehouse/parking lot (Excluding control room)

AREA 6: SUBSTATION
*substation from dead end structure through XFMR to equipment



AREA 7: CO2 PROCESSING
*CO2 compression and conditioning

- PRELIMINARY -
NOT FOR CONSTRUCTION

REV		DESIGN BY	CHECKED BY	DATE
A	Issued for Information	S. Sunby	---	OPEN

SVANTE
LAFARGE CO2 CAPTURE

Svante

Kiewit

PLOT PLAN OPTION 2

ENGINEER/DESIGN ORIGINATOR S. Sunby
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ENG MGR R. McLandsborough
PROJ MGR N. ROBINSON

DRAWING NUMBER
20035944-PP-001

SCALE IN FEET
SCALE: 1" = 30'-0"

Appendix I-3

LafargeHolcim Colorado Carbon Capture Project

Feasibility Study – LH CO_2MENT Colorado

Phase: FEL-2

COST ESTIMATING PLAN

Revision A

January 21st, 2022

SYNOPSIS

This Cost Estimating Plan is prepared for the ***LafargeHolcim CO_2MENT Carbon Capture Project*** for the proposed Portland cement plant located in Florence region, Colorado,USA.

This plan demonstrates the Kiewit Engineering Group' methodology for developing the capital and operating cost estimate deliverables for the Feasibility Study (FEL-2 phase).

Disclaimer

Rev.	Description	Originator	Review	Approval	Date	Customer Approval	Date
A	Issued for Information	DJM			1/21/22		

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Appendix 1: Kiewit Level 1-2 Account Codes
Appendix 2: LafargeHolcim Cost Area Map

1. INTRODUCTION

The LH CO_2MENT Project Feasibility Study is prepared for Electricore Inc. and Svante Inc. for the proposed carbon capture and associated facilities located in Florence region, Colorado. The Project Feasibility Study (FEL-2 phase) provides project definition as per scope, cost and schedule for project sanctioning. The cost estimate is one of many deliverables of the Project Feasibility Study.

This document presents the Cost Estimating Plan for the cost estimate portion of the carbon capture plant, pipeline and storage of the CO_2MENT Project Feasibility Study.

1.1 Objectives of this Plan

The Cost Estimating Plan has been developed to guide the feasibility study team through the appropriate stages of development to define the factored estimate and engineering Material Take-Off (MTO) deliverables. These deliverables form the basis of the cost estimate and will be issued to the Kiewit Estimating Department.

The cost estimate will provide cost details for capital costs of the proposed project.

Capital costs pertain to the engineering, procurement, construction, capital spares and commissioning of the new project.

The plan addresses the following issues:

- The estimate methodology and cost estimating principles applicable to the estimate preparation.
- The quality of the estimates required, in terms of the contingency and accuracy of the estimates.
- The MTO development philosophy for applicable major equipment and associated bulk material MTO's. This philosophy should be developed by engineering design, but minor equipment and associated bulk material MTO's can be factored by Estimating and priced with available in-house pricing data.
- The requirement to obtain firm quotations for major equipment items and budget quotations, historical/database information or by other techniques for minor equipment items.
- The components of the overall estimate and the estimating techniques to be used for each component.
- The estimate coding to allow sorting of data and ease of visibility of the estimate elements.

1.2 Control of the Plan

The Cost Estimating Plan will be reviewed and updated by the document originator to ensure relevant and consistent communication with the project team on MTO submission guidelines.

1.3 Project Description

To avoid discrepancies and misinformation, please refer to the Contract Scope of Work documents.

1.4 Acronyms and Definitions

The following acronyms/definitions in alphabetical order apply to this document:

- ASTM – American Society of Testing Materials
- BLDG – Building
- BOD – Basis of Design
- CAPEX – Capital Cost Estimate (expenditure)
- CMT – Kiewit Construction Management Team
- CM – Cubic Meters
- DBM – Design Base Memorandum
- DFL – Direct Field Labor
- EDS – Engineering/Design Specifications
- EPC – Engineering, Procurement and Construction
- EPCM – Engineering, Procurement and Construction Management
- EQPT – Equipment
- FEED – Front End Engineering Design
- KPI – Key Performance Indicator
- KPMP – Kiewit Project Management Process
- LSTK – Lump Sum Turn Key (Field Contract Type)
- MCC – Motor Control Center
- MH – Man-Hour (one hour of field construction work by a Trades Person of either gender)
- MHS – Field Construction “man”-hours by Trades People of both genders
- MT – Metric Tonnes
- MTO – Material Take Off
- MM – Man-Month (one month of field construction work by one Trades Person of either gender)
- MW – Man-Week (one week of field construction work by one Trades Person of either gender)
- N/A – Not Applicable
- NDE – Non Destructive Examination (testing procedure)
- OPEX – Operating Cost Estimate (expenditure)

- PEP – Project Execution Plan
- P&ID's – Piping and Instrumentation Diagrams
- PMT – Kiewit Project Management Team
- PO – Purchase Order
- QA/QC – Quality Assurance/Quality Control
- SPM – Smart Plan Material (procurement software program)
- SWGR – Switchgear
- TIC – Total Installed Cost
- TPC – Total Project Cost
- UoM – Unit of Measure
- WBS – Work Breakdown Structure
- UPS – Uninterruptible Power Supply
- XFMR – Transformer
- XMTR - Transmitter

2. KEY PERFORMANCE INDICATORS (KPI' S)

It is important for Kiewit to obtain feedback from customers on key Project Objectives and the project outcomes that reflect achievement of these objectives.

This is more pronounced for project execution outcomes but there are capital cost estimating KPI's on this estimate that can be measured against previous Kiewit carbon capture estimates per the appropriate unit of measure.

KPI's for the cost estimate will be developed throughout the pre-feasibility (FEL-1) and feasibility study (FEL-2). Comparisons to other go-by projects will be shown (as applicable). Some key capital cost KPI's would be:

1. TIC as a multiplier of total purchased process equipment;
2. Individual commodity code costs as % of TIC;
3. Engineering costs as % of TIC;
4. Contingency as % of TIC;
5. CAPEX cost per tonne of CO_2 capture.

3. ESTIMATE CLASSIFICATIONS & DEFINITIONS

The feasibility study estimate is a Class 4 Estimate with a -20% to +25% accuracy, consistent with the preliminary level of engineering detail available.

The Class 4 estimate acts as the stepping stone to project approval and economic evaluation. It is an integrated effort, and incorporates engineering, procurement, construction and estimating as a team to deliver a successful estimate.

A class 4 estimate provides:

- A mechanism for presenting to the Owner's Board of Directors for project sanction, with sufficient confidence in seeking project development financing.
- A project budget to monitor costs as the next "define" and "execution" phases start.

Cost estimates increase in accuracy at every phase during the development of a project.

3.1 General

Kiewit's Project Management Process (KPMP) defines the various stages of a project as noted below:

Table 1 KPMP Project Stage

IDENTIFY	SELECT	DEFINE	EXECUTE	OPERATE
Determine project feasibility and alignment with business strategy.	Select the preferred Development Option(s) & Execution Strategy.	Finalize project scope, cost and schedule and Sanction Project. Prepare for Execute Phase.	Produce an operating asset consistent with scope, cost & schedule.	Evaluate and operate asset to ensure performance to specifications and maximum return to Client.

The KPMP cost estimate classifications are commensurate with each of these stages, and consequently determine the level of effort required by all disciplines in producing the end product. The preparation of the estimate scope definition will be dependent on the level of quantification as the core of the capital cost estimate is the physical plant - its components and elements. The better the level of definition of these components and elements, the better the level of accuracy expected in purchasing and installing these items.

3.2 Classifications and Accuracy

Kiewit's cost estimate classifications are summarized in the following table:

Table 2 - Cost Estimate Classification

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges[a]	**PREPARATION EFFORT** Typical degrees of effort relative to least cost index of 1[b]
Class 5	0% to 2%	Concept Screening	Capacity factored, parametric models, judgment or analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget authorization or control	Semi detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 75%	Control or bid / tender	Detailed unit cost with some detailed take-off	L: -5% to -15% H: +5% to +20%	5 to 20
Class 1	65% to 100%	Check estimate or bid / tender	Detailed unit cost with take-off	L: -3% to -10% H: +3% to +15%	10 to 100

Notes:

(a) The state of process technology, availability of applicable reference cost data, and many other risks affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate application of contingency at a 50% level of confidence for a given scope.

(b) If the cost index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%.

3.3 Technical Definition

There is a minimum level of technical definition associated with each estimate class to realistically achieve the required accuracy. This is detailed in the following table:

Table 3 Technical Definition vs Classification

Classification	Technical Definition
IDENTIFY – Order of Magnitude	• Scenarios developed. • Locations of plant and main processes and facility types specified.
SELECT – Screening	• Major equipment specifications, flow diagrams, plot plans, location plans available. • Outline Basis of Design, Project Technical Specification and Project Strategy available. • Develop work breakdown structure. • Front End Loading (FEL) set up.
DEFINE – Control	• Choice of technology made. • BOD produced. • Project locations and ground conditions may be studied and surveyed. • Major equipment identified. • Flow and line diagrams prepared. • Quantified material take offs of bulk materials made. • Project schedule prepared. • Operations and maintenance needs defined. • Safety reviews begun.
EXECUTE – Definitive	• Major equipment ordered. • Design nearing completion. • Final material take offs of bulk materials made. • Major contracts let. • Construction commences.

3.4 General Contingency

Estimate classifications use different values of contingency. The contingency used in this class 4 estimate is further explained in section 7.8.

Contingency is “that amount required to bring the base estimate to a 50/50 estimate”; that is, where there is an equal chance of overrunning or under-running the estimate within its accuracy range.

For Class 5 and 4 estimates (Screening/feasibility), the expected contingency (as nominated in table 2) is considered, refined, and added as a single below-the-line component to the base estimate.

For Class 3 estimates (Control), the contingency is determined using a high-level risk analysis and discussed during each level of management reviews. The estimate is evaluated in parts which are assessed by the lead discipline engineers as well as department management, and division management. An overall contingency value is added as a single below-the-line component to the base estimate.

For Class 2 estimates (Definitive) as well as Kiewit EPC project execution, the same process as a Class 3 estimate occurs with the addition of cost variables (price/rate, quantity, productivity / schedule) and a likelihood of occurrence being applied to each risk item.

Using a combination of likelihood percentage and cost risk of each item, an overall job risk and contingency can be computed.

4. ESTIMATE OVERVIEW

4.1 Scope of Estimate

This estimate is a class 4 budget cost estimate as per the Kiewit “control” phase guidelines.

The cost estimate forms a portion of the LafargeHolcim CO_2MENT feasibility study for the proposed carbon capture and storage project, complete with Svante carbon capture process, CO_2 purification & compression, and overall project infrastructure.

The infrastructure entails buildings, site development, waste management, roads, drainage and utilities (electricity, natural gas, etc.).

The cost estimate shall be broken down in sufficient detail by Account Codes / Geographical areas and by equipment/structure to allow coding of contracts. The estimate should be flexible enough to be recast by Project Controls into a cost control budget to kick-start the detailed design phase.

4. 2 Estimate Schedule Dates

The Project Schedule is issued by Kiewit, and shall be the prime document of reference for schedule milestones and timelines. Interim dates for Engineering MTO’s shall be coordinated via weekly progress reviews.

4.3 Estimate Documentation Deliverables

The detailed cost estimate deliverables (capex) will be presented in electronic format. The estimate shall include all reports necessary for the customer to achieve project development sanctioning.

Cost estimate summaries will be organized by high-level Account Codes and by plant cost area.

Relevant backup information such as the basis of estimate narrative and budget quotes shall support the capital cost estimates.

The capital cost estimates shall be developed by the project team in a format consistent with the Customer's overall requirements.

4.4 Estimating General Strategy

The Capital Cost Estimate shall consider the EPCM "execution" strategy under the direction of Kiewit.

4.5 Estimating Resources

The Kiewit organization will provide the required Estimating personnel required to deliver the estimating deliverables for the feasibility study, with direction from Engineering, Procurement and Construction departments.

This work will be completed by a small sized dedicated team located in the Kiewit Lenexa office with part time estimating support from other Kiewit offices as required.

5. ESTIMATING SYSTEM

5. 1 System Overview

MS Excel and/or Bluebeam PDF software shall be used to present the cost estimate reports. Estimating software as well as industry standard estimate support data from SmartPlant, Universal Plant Viewer, Hard Dollar, IHS, and Svante or Kiewit's internal costing database may be used in the preparation of the estimating deliverables so as to execute the work within the budget allocated.

For this FEL-2 cost estimate, cost data will be generated from final Engineering MTO's, equipment quotations, engineering documents such as plot plans, one lines, P&IDs and load lists, as well as historical data from comparable sites. Local labor rates and up-to-date inflation and escalation data will be incorporated.

The estimating entries shall be coded as per the Kiewit account codes. The estimate formatting and coding will facilitate recasting of costing data into cost control budgets for the "execute" project phase.

6. CODING AND WORK BREAKDOWN STRUCTURE

The capital cost estimate data shall be coded in accordance with Kiewit account codes and standard estimating cost groups.

The account codes shall be coordinated with the Project Controls and Kiewit Estimating Department.

Relevant estimating data may be assigned additional coding as required for contracts, PO's, equipment tags and/or selective free form coding for data entry flexibility.

The following sections 6.1 and 6.2 demonstrate how the FEL-2 estimate cost breakdown aligns with the Kiewit account codes.

6.1 Account Code Overview

The Project account codes are detailed in Appendix 1. The major discipline elements of the Kiewit level 1 (highest level) account codes are as follows, in the numerical order they appear in the Kiewit billing system.

- Overhead
- Operational Support
- Removals and Demolition
- Grading
- Civil Utilities
- Aggregates and Paving
- Temporary Work
- Deep Foundations
- Concrete
- Metals
- Piping
- Mechanical Equipment
- Water and Wastewater Equipment
- Startup and Performance Testing
- Process Insulation and Refractory
- Building
- Misc Specialty Work
- Engineering
- Construction Equipment
- Discipline Services, Tools and Supplies
- Direct Estimated ST&S
- Bulk Commodities
- Engineered Equipment
- Subcontracts

6.2 Estimate Cost Overview

The Kiewit estimate pricing sheet puts costs into groups that are consistent with the above account code number schemes. A detailed description of each cost is below. They are a mix of level 1 and level 2 account code depths of detail. Using these categories allows for accurate quantity-based pricing, and also for clear demonstration of where a project's costs exist.

<u>50 – Removal and Demo</u>
This cost includes labor, consumables, removal cost/dump fees, and subcontractors to support project demolition. This section is to describe the preparation of the site prior to any Civil or grading activities. Removal of existing buildings, foundations, any type of utilities that may need to be relocated to support the current project.

Structural Exc./Backfill - This cost includes excavation, hauling, stock piling and backfill for foundations. This would also include excavation for buried tanks, electrical manholes and vaults.

Mech/Elec Support - This cost includes the excavation, hauling, stock piping and backfill to support underground piping and ductbank trenches.

SiteWork - (Mass Excavation and/or building up the jobsite to the construction elevation). This includes clearing and grubbing, mass soil stripping, hauling and stockpiling associated. This code also includes placing final topsoil at the final elevation.

<u>51 – Grading Summary</u>
This encompasses all mass earthwork, subgrade preparation and soil additives for stabilization. This also includes permanent fences, gates, and guardrail. Items considered incidental to construction include construction water, dewatering and erosion control are also included here.

<u>52 – Civil Utilities</u>
This cost includes site utilities specific to civil such as storm water drainage and culverts. This would also include underground exploration at brown field sites such as potholing and ground penetrating radar.

<u>53 – Aggregates & Paving</u>
This cost code includes labor and materials for paving permanent roads, parking areas and sidewalks. This includes the final yard stone to bring the site to final grade.

<u>60 – Deep Foundations</u>
This cost code includes major structural foundation features such as piles, piers, or major ground improvement to support critical foundations.

<u>61 – Concrete</u>
The cost code includes the cost for labor, permanent materials, consumables, and subcontractors to support equipment foundations, mudmat and ductbank. This cost code also includes the purchase and set cost for electrical manholes, precast cable trench, precast sumps and precast light pole bases.

<u>62 – Metals</u>
This cost code includes the cost for labor, permanent materials, consumables, and subcontractors to support the structural steel and steel pipe rack construction. This includes stairs, ladders, railings and grating.

<u>70 – Pipe</u>
This cost code includes labor, permanent materials, consumables for all things related to piping. This includes handling, welding, hydro testing, PWHT/NDE, valve/ in line components installation, pipe support installation, etc.

71 – Mechanical Equipment Summary
This cost code includes the labor and consumables used for installing equipment. This includes offloading, set and align. Heavy haul, special rigging, major OEM assemblies/sub-assemblies including ductwork would be covered in this cost code.

73 – Startup
This cost includes all costs related to hot and cold equipment checkout, trouble shooting, , startup staff and specialty 3rd party consultants or subcontractors, electrical testing, system flushing, steam blows (if required), instrument and pipe support checkout.

74 – Process Insulation
This cost includes the purchase and installation labor for installing piping, equipment and ductwork insulation and aluminum jacketing for the project.

81 – Electrical
This cost includes the purchase and installation labor for installing electrical equipment, wire, conduit and raceway, grounding, lighting, heat trace, cathodic protection, security, communications, consumables etc. Major equipment such as large transformers, PDCs, MCCs are covered in code 94.

81 – Instrumentation
This cost includes the purchase and installation labor for instruments and instrument tubing. Includes consumables. This does not include the cost of the instruments or the DCS, which is covered in code 94.

83 – Buildings
This cost would cover building related scope outside of a subcontractor. Masonry, finishes, furnishings, HVAC etc.

87 – Misc Specialty Work
This cost includes all finish painting and coatings subcontracts.

88 – Engineering
This cost covers the engineering and early planning stages of the project. Engineering activities include process design, calculations, 3D model, construction drawings, vendor contract administration, construction support, procedures, studies, specialty 3rd party consultants, and temporary construction design, if needed.

90 – Construction Equipment
This cost includes major construction equipment rent, fuel and maintenance cost.

91 – Small Equipment Purchases
This cost includes small services, tools and supplies to perform the work (items less than $25,000).

94 – Engineered Equipment
This cost includes all the major permanent engineered equipment that is designed, specified and purchased for the project.

20 – Job Related Overhead
This cost includes construction project management and support staff expenses such as living and travel. This also includes jobsite trailer rent, setup and teardown.

Roads, Parking & Laydown
This cost includes all work to develop temporary facilities such as craft and staff parking, laydown, heavy haul roads, crane pads, temp fencing and gates. This code also includes environment restoration to original soil conditions.

Temporary Electrical
This cost includes the cost for installation, maintenance, and removal of temporary electrical equipment to support construction and startup activities. This may also include the cost of the consumption of power during the construction period.

Temporary Scaffolding
This includes scaffolding cost for construction or startup related activities.

Escalation (PM, EE, AND SUBS)
This cost is used to estimate the price escalation from the start of the project to the end of the project.

30 – Operational Support Summary
This cost includes the major indirect costs of a construction project. These costs include safety, environmental, procurement, IT and HR staff, for example. Other items covered in this cost code include jobsite mobilization/demobilization.

40 – Contingency
Contingency is carried to cover unknown costs or risks of a project. Typical contingency varies depending on the contract model for the scope, project complexity and design maturity.

10 – Commercial Cost
This cost includes licenses, permits, taxes, fees and insurance to support a construction project start to finish.

7. ESTIMATING METHODOLOGY

Kiewit is an industry leader with extensive history, lessons learned and tools geared towards accurate and expedient process industry estimates. Coupling a decades of relevant construction experience and data with a state of the art engineering partner, the integrated design approach will take the best that engineering and construction have to offer. This construction and engineering integration yields the lowest total installed cost, foregoing one party increasing the overall total job cost to save their entity a bit of money.

MTO quantities are generated for Kiewit Class 4 estimates through various deliverables such as steel 3D models, piping and instrumentation diagrams, plot plans, one lines and process flow diagrams. Construction task hours and costs shall be developed based on these quantities and based on equipment scope. The equipment scope, quantities and costs are generated from firm price quotations, budget quotations or in-house historical databases.

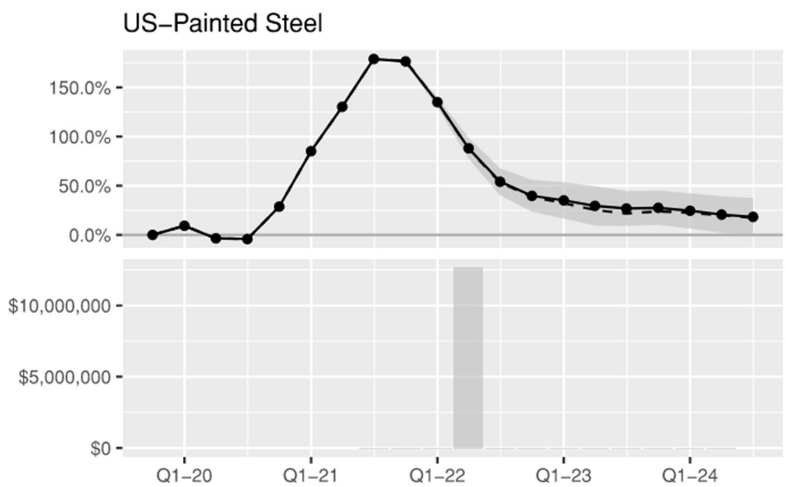
For the FEL-2 estimate, Kiewit and Svante agreed a unique breakdown of costs would be beneficial. The FEL-2 estimate was split into 7 cost areas as directed by Svante. Each cost area represents an aspect of a typical plant, and can be used for comparing this project to other Svante capture projects, even when differences in the projects exist. A full breakdown of these costs is explained in section 7.9, and a visual representation of these areas is in Appendix 2.

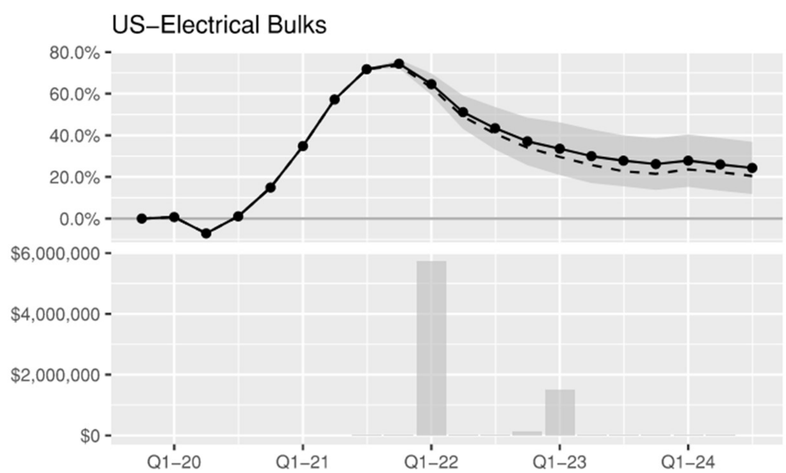
7.1 General Pricing and Project Cash Flow

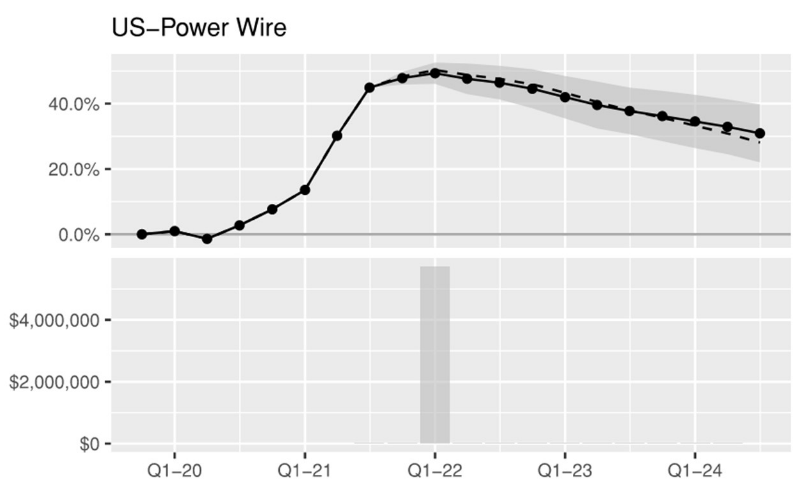
All costs will be in December 2021 US dollars. Escalation throughout the project is incorporated into the cost. Escalation for a delayed start date shall be the responsibility of the owner.

It should be noted that unusual escalation and inflation have occurred worldwide due to the Covid-19 pandemic. Caution should be taken when comparing the price for LafargeHolcim to another project with pricing from 2019 or 2020, for example.

A few key commodity price changes are demonstrated in the charts below.







7.2 Estimate Structure

The capital cost estimate detail will show EPCM, construction, startup, and commissioning costs.

EPCM hours and expenses shall be identified by the Kiewit project team.

Construction costs are broken down into two major categories; direct and indirect costs:

- Direct costs are the permanent facilities and services required for their installation. Further subdivisions of these costs are broken into facility WBS and commodity codes as described in section 6.
- Direct costs include direct material, construction crew labor and sub-contract costs:
  - Direct material comprises plant equipment and bulk material.
    - Plant equipment includes the mechanical equipment (shown in the equipment list), electrical equipment (XFMRS, SWGR, MCC's, etc.), instruments and control system components of a plant, which are either off-site shop assembled, module yard assembled or on-site pre-assembled in a field-fab shop prior to final installation.
    - Bulk material comprises those materials, such as pipe, wire, concrete, steel etc., which are required to support and hook-up the plant equipment.
- Indirect Costs are the costs associated to support the installation of the direct costs. This includes the materials and services required for field construction.
  - Contractors' items such as safety indoctrination, warehousing of Contractors' direct material, site access vehicles, scaffolding, construction trailers, Contractors' office overheads, etc.
  - Common distributable include general items coordinated by the Owner such as spares, freight, Vendor Representatives, HSE procedures, re-fueling of construction equipment, warehousing of Kiewit purchased equipment, temporary facility services (storage & heating, fencing, public washrooms, etc.), temporary utilities, potable water distribution, waste debris removal, road maintenance, snow clearing, site security, etc.

7.3 Quantities

MTO quantities are the basis for many costs in the estimate. Man-hour factors derived from decades of region-specific and industry-specific work are coupled with material quantities to develop an accurate cost for construction labor. By using factors applied to quantities as opposed to industry factors of equipment costs, a higher level of granularity and accuracy is gained.

7.4 Equipment and Material Pricing

Typically a class 4 estimate will not have much or any equipment costs directly quoted with up-to-date and project-specific pricing. The Kiewit team used their extensive supplier network and obtained 7 vendor quotations for the FEL-2 estimate.

The equipment quoted was flue gas, reflux, product gas, and conditioning air blowers, conditioning air heaters, steam boilers, CO_2 compressors, cooling vessels, hydrogen generators and Triethylene glycol moisture separation systems.

Equipment not directly quoted will be priced by the Kiewit estimating group, as usual, using historical comparable equipment.

Equipment pricing generated by Kiewit has startup, technical field assistance, spares, modularization, bond, 1 year warranty, shipping to jobsite, and tax included. While an attractive equipment price may contain less scope than that, Kiewit's experience has shown that in the EPC space, these types of items including performance guarantees and liquidated damages on certain equipment are mandatory.

7. 5 Labor Pricing

As discussed previously, unit man-hour base rates of placement for equipment and materials will be developed and agreed with the Kiewit Project team. Base rates are developed for the specific geographical region using Kiewit's local and up-to-date rates based on knowledge of the region. Canadian estimate teams internal to Kiewit are engaged for labor rate checks, appropriate work classifications, and man hour factors. A high degree of accuracy is expected with these rates due to Kiewit's extensive and local experience.

Productivity and labor pricing is influenced by a number of factors which include the following:

- Project Type (Green or Brown field)
- Project Location
- Availability of labor
- Language and culture
- Contract type i.e. performance incentives, direct hire, lump sum etc.
- Contractors' supervision efficiency assessment
- Craft labor experience
- Crew mix requirements
- Modularization, off-site pre-assembly or stick-built construction methodology
- Site working conditions (work week, shifts, elevations, weather, dust, etc.)
- Non-productive time (bussing of workers to work areas, work permit procedures, safety procedures and access to stored construction material
- Site access for construction equipment
- Design complexity

7.6 Allowances

This section deals with allowances that are generally considered as "unknowns", i.e. requirements through the normal evolution of engineering, procurement and construction.

Allowances include general estimating allowances, specific design allowances and price quotation allowances.

General estimating allowances include fabrication wastage, construction over-pours and normal minor rework in the field.

Design allowances are incorporated into unit rates that are applied to quantities. For example, recent install cost-per-foot of small bore 2” carbon steel is included in the Kiewit estimate considering that pipe ships in 20 foot spools from a fabricator. Since not every run of small bore pipe is a multiple of 20 feet, there will be some wastage or scrap pipe.

Allowances are distinct and separate from Contingency (see section 7.8).

7.7 Third Party Inspection and Testing

Third party inspection and witness testing of purchased equipment in the suppliers’ shops or in module assembly yards shall be included in the equipment cost (account code 94 above).

7.8 Contingency

Contingency is an allowance added to cover for project execution unknowns, risks and uncertainties, that traditionally occur on projects but which are not evident by the project team in the initial planning stage. Such unknowns could be incomplete project definition, market forces or estimate omissions. Kiewit’s extensive experience yields a lower contingency cost than may be expected at first. Risk mitigation is a key factor in the assessment of the contingency value. During the estimate review process, multiple different management levels are consulted to develop the contingency cost.

The amount of contingency carried is less than 10%. It has been reduced from a typically higher value due to the confidence level of the Kiewit FEL-2 estimate efforts. Actual vendor quotations for sized high cost equipment were one price component that increased accuracy above a typical class 4 estimate. Furthermore Kiewit's recent and vast database of equipment quotations and labor rates in the region add to the accuracy of the estimate, reducing the need for more contingency. Kiewit’s practice of risk assessment that applies probabilities to each potential risk helps focus the contingency cost on the truly unknown. Finally, Kiewit’s extreme low (less than 2% of contract value) average contractor change order total per job in the last 7 years lends credence to our lower than typical contingency, due to our higher accuracy in cost forecasting.

Approved scope changes are handled with a pre-defined “Project Change Order Procedure” resulting in additional budget funding.

7.9 Cost Areas

As previously mentioned, the estimating team broke every single account code cost into one, or multiple cost areas. The seven areas are defined as:

Area 1: Direct RAM components, foundations, steel for the RAM
Area 2: Process Stream BOP: ductwork, steel, conditioning air, reflux, blowers and motors

Area 3: Site BOP for cooling system, water treatment, tanks
Area 4: Site Infrastructure: earthwork cut and fill, roads, drainage, lighting
Area 5: Steam generation, associated foundations and electrical
Area 6: Substation
Area 7: CO2 Processing: CO2 compression, moisture removal, metering

Each cost area includes ancillary costs such as contingency, escalation, overhead, management, operational support, margin and G&A. This extra work creates the clarity to see what the real, fully built and commissioned cost is per area.

These seven areas, shown in greater detail in Appendix 2, shine light on where the costs are for carbon capture projects like LafargeHolcim. For example, a project with substantial steam generation equipment compared to a project using existing steam capacity from an existing facility will yield a different total cost. But by using cost areas, the cost of steam generation equipment can be set aside, and a true ‘’apples to apples’’ comparison between plants can be made. This comparison works not only on Svante to Svante comparisons, but also with solid sorbent to liquid amine technologies.

This will help Svante and Kiewit demonstrate the true cost of solid sorbent carbon capture, as well as identify the best sites and plants to add carbon capture to. By seeing where costs lie, the most viable and most economical sites and projects can be chosen. This work creates direct value to existing and future clients.

7.10 Engineering Deliverables

Certain deliverables are required to be made to meet the FEL-2 agreement. Kiewit will generate those deliverables, but in addition, other deliverables are made to assist the Kiewit Estimating team and enhance the estimate accuracy. Estimating and Engineering will agree on the deliverables prior to the estimate team starting work. This, combined with the schedule of the FEL-2 timeline, allows the Kiewit estimating team to allocate the appropriate resources to support the estimate.

Engineering Deliverables and other information from all disciplines are given to Estimating to allow Estimating to populate the estimate cost sheet. All deliverables to estimating are housed on an internal Kiewit sharepoint website.

The following general deliverables are developed for the estimate team:

7.10.1 General Information

- A brief deliverables “basis of design” narrative from Svante in the project charter identifies project scope assumptions and exceptions affecting project engineering deliverables.
- A Cost area map and description of each cost area, as described above in section 7.9. The estimate team is walked through this map and process in detail at the estimate kickoff to ensure that the right costs go in the right ‘buckets’.
- A Basis of Estimate template for each engineering discipline8 as well as the construction group to populate. The purpose of this is to get all design assumptions and estimate bases documented. This data is transferred into documents like the FEL-2 report to explain the basis of design, cost and schedule.

7.10.2 Piping

The following are the piping MTO deliverables required to develop the CAPEX:

- P&ID set – One of the most impactful deliverables generated, the P&ID set displays each pipeline, size, purpose, heat trace and/or insulation, material and pressure class. Valve information, pipe weight, routing direction, maintenance spacing and instrument counts can all be gleaned from P&IDs.
- Plot Plan – This layout helps develop MTO quantities by communicating spacing and potential pipe routings between equipment. It helps locate underground trenches for MTO quantities, as well as access and maintenance pathways.
- Site Plan – This aides in locating the utility tie in points. Combined with the plot plan, accurate lengths of HV Transmission lines, potable water lines, wastewater discharge piping, steam tie ins, natural gas pipelines, and river water piping can be calculated and priced.
- Line List – Used in conjunction with pipe specs, the valve list and plot plan are used to develop pipe lengths, costs, weld lengths and locations, rack spacing, insulation costs and many other values.
- Piping Specifications – These are developed to identify piping type (Victaulic or conventional welded/flanged fittings), material, pipe schedule and valve class, etc. for specific plant systems. This information is communicated to the estimate group on the P&ID set using pipe line number data. The pipe specs are Kiewit’s standard robust and fully built out specs used in EPC production work.
- Water balance – The balance is indirectly used to generate water system quantities of pipe. It is directly used to develop the P&ID data, which is then used for takeoff and pricing.
- The Shop spooling / pre-assembly philosophy is Kiewit standard for the lowest total installed cost, modularizing and pre-fabricating where cost benefits exist.
- Any vendor equipment general arrangements are also given to the estimate team, as piping for equipment that ships loose can be counted.

7.10.3 Mechanical

In addition to the above section’s deliverables, the following are additional mechanical deliverables deemed necessary to develop and support the estimating process:

- Any equipment quotations, weights, sizes and power consumptions from vendors. These quotations have datasheets which provide impactful information for sizing lines, flows, and designing mechanical systems.
- RAM Erection sequence – This document was generated for the Svante Chevron project. It includes detailed erection instructions for the RAM and its ancillaries. This sequence was used to price up the labor and equipment needed to handle and install the RAM at LafargeHolcim.
- All valve MTO’s sorted by pipe spec and line number are available as an output of the P&ID data set. This is housed in a valve list, as well as on the P&ID set. This includes control valves, safety valves, and manual valves.

- Minor equipment data sheets for miscellaneous equipment to be estimated.

7.10.4 Structural

The following are the Structural deliverables deemed necessary to develop the estimate:

- Foundation drawings – The FEL-2 structural engineering team generated dimensioned foundation drawings for key equipment at the capture plant. These were sent to the estimating team for material take off and quantity development. These extra steps generate accurate costs for labor and materials.
- Steel Pipe rack and flue gas duct rack dimensioned 3D and 2D models - The FEL-2 structural engineering team generated 3D models of the steel racks that convey piping around the capture plant. These were sent to the estimating team for material take off and quantity development. The model provides a more accurate output of steel tonnage than scaling or factoring off of other projects. These quantities will be used to develop labor and construction equipment costs.

7.10.5 Civil

The following are the civil deliverables deemed necessary to develop the estimate:

- Plot plan – The plot plan conveys ground surface square footage data for pricing up road and aggregate costs.
- Site plan – This coupled with the plot plan and the geographic area can be used to generate civil grading plans and heat maps. A heat map quantifies the dirt cut and fill amounts in cubic yards.

7.10.6 Electrical

The following are the electrical deliverables required to develop the estimate:

- Plant equipment list with electrical load ratings – This aides in generating the electrical one line for the plant. Cable sizing and copper quantities can be obtained, along with costs and labor.
- Switchyard layout – This will detail out breakers, H frame surge arrestors, low and high bus supports, disconnect switches, and transformers. The size of the layout can help develop civil and grading costs, fencing and lighting costs and quantities too.
- Switchyard one line – Aides in developing MTO for HV lines.
- Plant electrical one line – The estimate team can calculate cable lengths, sizes, costs and labor from this and the plot plan.
- Plot plan – To be used to generate the MTO for lighting and grounding.

7.10.7 Instrumentation and Control

The following are the instrumentation and control activities required to develop the estimate:

- P&ID set – This lists out all instruments and associates them with a line number, correlating pressure temperature and material. From this, a detailed cost of instruments can be generated from an instrument take off of the P&ID set.

- Plot plan – Generates Bulk material MTO for cables, raceway, junction boxes, etc.

7.11 Plant Equipment List

The equipment list includes the following data:

- Equipment Tag Number
- Location on P&ID set
- Corresponding cost area bucket
- Basis of pricing to be used (historical, scaled, factored, or actual vendor quotation)
- Equipment Description

8. ESTIMATE DEVELOPMENT RESPONSIBILITY MATRIX

Detailed below is an estimate overview chart. It lists the main estimate components and the responsible department for supplying that data.

Table 4 Estimate Overview Chart	
Scope	**Responsibility**
1. Scope Definition, Documentation and Execution Strategy	Estimate Team Manager
2. Quantity and Pricing Development	
Major and Minor Equipment	
Equipment list of all process and utility equipment.	Engineering Services
Prices quoted by Suppliers/Contractors, current market pricing information, inland & ocean freight rates, import duties if required, vendor representative rates and expenses.	Engineering Services / Estimating
Construction installation methods and labor productivity. Taxes, foreign currency issues and import duties.	Estimating
Major equipment estimate, including review of scope, material and labor pricing.	Estimating
Bulk Quantity Development	
Capex MTO's plus scope of work, assumptions and exceptions.	Estimating
Capex estimating methodology Modularization and/or pre-assembly strategy	Estimating
Opex cost estimate.	Engineering Services
3. Field Labor Pricing	
Establishing and updating field installation labor hour standards. Manual labor productivity, wage rates and craft mix.	Estimating
Composite wage rates.	Estimating
4. EPCM Estimate of Hours	
Engineering job hours and expenses. Management Estimate of hours and expenses. Total cost of EPCM.	Engineering Services / Estimating
5. Escalation Analysis	
Escalation rates beyond bid date shall be the responsibility of the Owner. Escalation of historical prices to current bid date is the responsibility of Kiewit.	Engineering Services / Estimating
6. Contingency Analysis	
Development of contingency pricing and basis/probability for contingency.	Engineering Services / Estimating
7. Estimate Reviews	
Estimating Internal Review	
A "cold eyes" review of estimate format and formulae shall be conducted by the project manager knowledgeable of the LH CO_2MENT pre-feasibility study, but not responsible for the majority of the cost generation work. The intention is to catch any "mechanical errors" before any formal reviews are held.	
Peer Review (KPC third party)	
An independent peer review shall be conducted by a third party source within Kiewit (global) to review unit rates and current comparable jobs applicable to the local industrial scene in Colorado or similar areas.	
Senior Management Review (Internal to Kiewit)	
Kiewit Senior Management shall review the estimate in detail, specifically G&A, margin, and contingency, and will apply past project "lessons learned" to provide the due diligence required prior to the formal review with Owner.	
Svante/Kiewit Review (Cost and Scope)	

A cost and scope meeting is held to ensure the estimate detail has been completely and correctly quantified for all direct account categories according to the scope document. This meeting is a team review of scope and quantity details for each account code, and it is a key review of the direct account quantities where agreement on the total package must be reached among all attendees. If Svante has performed a prior estimate, the scopes and individual costs of each account code shall be compared. The code scope shall be discussed to ensure an apples-to-apples comparison is being made.
The engineering confidence levels shall be confirmed at this review meeting and the data used to revise the contingency if required.
This meeting may occur multiple times if lengthy scope or cost discussions are needed.
Client Review
This meeting is chaired by the Svante Project Manager and Svante management team, with the customer's representative, Kiewit Project Manager, Kiewit management team, and the lead estimator (optional) as participants.

APPENDIX 1: KIEWIT LEVEL 1-2 ACCOUNT CODES

Below is a summary of the Kiewit account codes, down to the second level of codes. These serve as the basis for grouping costs in an estimate as well as setting up budgets for an executed project.

Account Code	Description	Primary UOM	2nd UOM
00	Overhead	PLS	
00.03	OH - Get Work	MWk	K$
00.06	OH - Build Work	MWk	MH
00.09	OH - Manage Assets	MWk	PLS
10.03	G & A Expense	K$	
10.09	First Nations Fee	K$	
10.12	Bonds	K$	
10.15	Insurance	K$	
10.18	Cost of Financing	K$	
10.21	Licenses, Permits, Taxes and Fees	K$	
10.24	Dues, Donations and Community Support	K$	
10.27	Shared Services (not part of 30.03)	K$	
10.30	District Shop Expense	K$	
10.33	Disputes Review Board	K$	
10.36	Legal Expense	K$	
10.39	Compensable Pre-Bid Cost	K$	
20.03	Project Management	MWk	
20.06	Staff Expenses	MWk	
30	Operational Support	PLS	
30.03	Operational Support and Compliance	MWk	
30.06	Temporary Work	PLS	
30.09	Craft Labor Support	PLS	
30.12	Provisional Cost Assignments	PLS	
40.03	Project Risk	K$	
50	Removals and Demolition	PLS	
50.03	Civil Demolitions	PLS	
50.06	Mechanical and Electrical Demolition	PLS	
50.09	Other Demolition	PLS	
50.12	Track Work Demolition	TF	
50.15	Cutting and Coring	PLS	

50.18	Hazardous Material and All Disposal	PLS	
50.20	Haul Demolition Material	PLS	
50.98	Subcontractor Assistance Removals and Demolition	PLS	
50.99	Specialty and Unique Removals and Demolition	PLS	
51	Grading	PLS	
51.03	Site Clearing / Soil Stripping	Acre	
51.06	Excavation and Embankment	PLS	
51.09	Fragmentation	CY	
51.12	Subgrade Prep / Finish	PLS	
51.15	Structural Excavation and Backfill	PLS	
51.18	Mechanical and Electrical Excavation and Backfill	PLS	
51.21	Retaining and Sound Walls	PLS	
51.24	Slope Protection	PLS	
51.27	Dewatering	PLS	
51.30	Soil Stabilization	PLS	
51.33	Excavation Support and Protection	PLS	
51.36	Civil Thermal Control	SF	CF
51.40	Dams & Dykes Instrumentation	PLS	
51.45	Misc Civil	PLS	
51.48	Environmental	PLS	
51.98	Subcontractor Assistance Grading Work	PLS	
51.99	Specialty and Unique Grading Work	PLS	
52	Civil Utilities	PLS	
52.03	Utilities Misc	PLS	
52.06	Utility Ex Lay Backfill Piping	PLS	
52.09	Manholes / Utility Boxes	PLS	
52.12	Storm Drain Structures and End Treatments	PLS	
52.13	Other Drainage	LF	
52.15	Wells	PLS	
52.18	Ponds, Reservoirs, and Containments	PLS	
52.24	Buried Electrical / Communications Utilities	PLS	
52.30	Trenchless Utilities	LF	
52.80	Civil Utilities Concrete Accessories and Rebar	PLS	
52.98	Subcontractor Assistance Civil Utilities Work	PLS	
52.99	Specialty and Unique Civil Utilities Work	PLS	
53	Aggregates and Paving	PLS	
53.03	Paving Rehabilitation	SY	
53.06	Aggregates	PLS	

53.09	Asphalt Paving	PLS	
53.10	Concrete Paving	SY	CY
53.12	Concrete - Saw and Seal	PLS	
53.15	Unit Paving	SF	
53.18	Curbs, Gutters, Sidewalks, and Driveways	PLS	
53.21	Permanent Concrete Barrier	LF	
53.24	Material Processing and Plants	PLS	
53.98	Subcontractor Assistance Aggregates and Paving	PLS	
53.99	Specialty and Unique Aggregates and Paving	PLS	
54	Temporary Work	PLS	
54.02	Traffic Control	Wk	
54.04	Maintain Existing Facilities	PLS	Wk
54.06	Temporary Electrical - Setup, Maintain and Remove Labor	PLS	Wk
54.08	Temporary Scaffold Labor	DMH	CF
54.09	Temporary Walkways and Railing	LF	
54.10	Temporary Bridge	SF	
54.12	Trestle Access	SF	
54.14	Temporary Railroad Spur / Crossings	Ea	
54.16	Falsework	SF	CF
54.18	Heating and Hoarding	SF	
54.20	Ice Bridges	SY	
54.98	Subcontractor Assistance - Temporary Work	PLS	
54.99	Specialty and Unique Temporary Work	PLS	
58.03	Traffic Control	Ea	
58.06	Roadway Debris/Amenities	Ea	
58.09	Roadside Operations	LMi	
58.12	Roadside Maintenance	Acre	
58.15	Roadway	SY	
58.18	Drainage	LF	
58.21	Structures	SF	
58.24	Fence/Walls/ Sound Abatement	SF	
58.27	Earthwork/Embankments/Cuttings	SY	
58.30	Traffic Signs	Ea	
58.33	Lighting/Signals/ITS	Ea	
58.36	Track work Maintenance	TF	
58.39	Customer Response	Yr	MWk
58.98	Subcontractor Assistance Routine Maintenance Work	PLS	
58.99	Specialty and Unique Routine Maintenance Work	PLS	

60	Deep Foundations	PLS	
60.03	Driven Pile	PLS	
60.06	Direct Embedded Transmission Pole Foundations	PLS	
60.09	Caisson	PLS	
60.11	Drilled Shafts	Ea	LF
60.14	Grouting	CY	CF
60.15	Secant Pile Wall Shafts	SF	Ea
60.17	Tangent Pile Wall Shafts	SF	Ea
60.19	Micropiles	Ea	LF
60.21	Auger Cast Piles	Ea	LF
60.22	Helical Piles	LF	Ea
60.23	Stone Column Ground Improvement	Ea	LF
60.25	Soil Mixing	CY	SF
60.27	Slurry / Cutoff Wall	SF	CY
60.30	Batch Plant Fixed Costs - Slurry Plant	Ea	
60.35	Drainage Relief Holes	LF	
60.90	Foundation Testing	Ea	
60.93	Tooling Maintenance Labor	LF	
60.98	Subcontractor Assistance Deep Foundations	Ea	LF
60.99	Specialty and Unique Deep Foundations	PLS	
61.03	Non-Support Horizontal Concrete	CY	
61.06	Vertical Formed Concrete	CY	
61.09	Supported Concrete	CY	
61.11	Hydro Concrete	CY	
61.12	Other Concrete	CY	
61.15	Traveler / Slip Forms	CY	
61.18	Precast	CY	
61.20	Precast (Permanent Yard)	CY	
61.21	Thermal Control	CY	
61.24	Concrete Accessories	CY	
61.27	Rebar and Accessories	Ton	CY
61.30	Embedded Items	Ea	Lb
61.40	Concrete & Structure Instrumentation	Ea	
61.80	Concrete Rehab / Repairs	CY	SF
61.98	Subcontractor Assist Concrete Work	PLS	
61.99	Specialty and Unique Concrete Work	PLS	
62.03	Structural Steel and Connections	Ton	
62.06	Wire Rope	PLS	

62.09	Metal Joists (Bar Joists)	PLS	
62.12	Metal Decking	PLS	
62.15	Specialty Bridge Metals and Machinery	PLS	
62.18	Misc Metals	PLS	
62.21	Misc Metals Fabrication	PLS	
62.98	Subcontractor Assistance Metals Work	PLS	
62.99	Specialty and Unique Metals Work	PLS	
70.06	Shop Pipe Fabrication	DI	LF
70.07	Module Assembly Piping - OnShore	LF	
70.09	Field Spool Fabrication	LF	
70.12	Above Ground Piping	LF	DI
70.15	Underground Piping	LF	DI
70.21	Valves - Requiring Special Handling	Ea	
70.23	Temporary Specialty Piping	LF	
70.25	Pipeline Piping	LF	
70.98	Subcontractor Assistance Piping Work	PLS	
70.99	Specialty and Unique Piping Work	PLS	
71	Mechanical Equipment	PLS	
71.03	Mechanical Equipment - General	Ea	
71.06	Mechanical Equipment - Power Generation	PLS	
71.09	Mechanical Equipment - Pollution Control	PLS	
71.12	Mechanical Equipment - Oil, Gas and Chemicals (OGC)	Ea	
71.15	Mechanical Equipment - Material Handling and Processing	LF	
71.18	Mechanical Equipment - Food and Beverage	Ea	
71.21	Mechanical Equipment - Heavy Equipment and Specialty	PLS	
71.24	Mechanical Equipment - Pulp and Paper	PLS	
71.27	Mechanical Equipment - Metal Mills	PLS	
71.30	Mechanical Equipment - Mineral Processing / Mining	PLS	
71.92	Mechanical Equipment - Field Fabricated Tanks	Gal	Ea
71.94	Mechanical Equipment -Tank Refurbishment	Gal	Ea
71.98	Subcontractor Assistance Mechanical Equipment Work	PLS	
71.99	Specialty and Unique Mechanical Equipment Work	PLS	
72	Water and Wastewater Equipment	PLS	
72.03	Screens	Ea	
72.06	Screenings Washing and Compacting Equipment	Ea	
72.09	Grit Removal and Handling Equipment	Ea	
72.12	Grinders	Ea	
72.15	Aeration / Mixers	Ea	

72.18	Air and Gas Diffusion Equipment	Ea	
72.21	Clarifiers (FT = DIA)	Ft	Ea
72.24	Flow Control and Gates	Ea	
72.27	Chemical Feed Equipment	PLS	
72.30	Ozone	PLS	
72.33	UV Equipment	Ea	
72.36	Filtration Equipment	Ea	
72.39	Reverse Osmosis Equipment	PLS	
72.42	Digester	Ea	
72.45	Covers	Ea	
72.46	Odor Control	PLS	
72.48	Solids Dewatering	PLS	
72.51	Misc Water Treatment Equipment	PLS	
72.98	Subcontractor Assistance Water and Wastewater Equipment Work	PLS	
72.99	Specialty and Unique Water and Wastewater Equipment Work	PLS	
73	Startup and Performance Testing	PLS	
73.03	Pre-Commissioning (Cold Commissioning)	PLS	
73.06	Commissioning (Hot Commissioning)	PLS	
73.09	Operational Testing	PLS	
73.12	Commissioning & Startup (CSU) Craft	Ea	
73.98	Subcontractor Assistance Startup and Performance Testing Work	PLS	
73.99	Specialty and Unique Startup and Performance Testing Work	PLS	
83	Building	PLS	
83.04	Masonry	PLS	
83.06	Woods, Plastics, and Composites	PLS	
83.07	Thermal Moisture Protection	PLS	
83.08	Openings	PLS	
83.09	Finishes	PLS	
83.10	Specialties	PLS	
83.11	Building Equipment	PLS	
83.12	Furnishings	PLS	
83.13	Special Building Construction	PLS	
83.23	Heating, Ventilating, and Air Conditioning (HVAC)	BGSF	
83.98	Subcontractor Assistance Building Work	PLS	
83.99	Specialty and Unique Building Work	PLS	
87	Misc Specialty Work	PLS	
87.03	Painting and Coatings (Non-Building)	SF	
87.05	Painting and Coatings (Building)	SF	

87.98	Subcontractor Assistance Specialty and Unique Work	PLS	
87.99	Specialty and Unique Work	PLS	
88	Engineering	PLS	
88.01	Design Engineering Indirects	PLS	MH
88.05	Design Engineering Expenses	PLS	MH
88.10	Design Engineering - Consultants	PLS	MH
88.30	Design Engineering - Electrical	PLS	MH
88.35	Design Engineering - Instrumentation and Controls	PLS	MH
88.40	Design Engineering - Civil	PLS	MH
88.45	Design Engineering - Structural	PLS	MH
88.50	Design Engineering - Geotechnical	PLS	-
88.55	Design Engineering - Building	PLS	MH
88.60	Temporary Structures & Construction Devices (TSCD) Design	PLS	MH
88.65	Design Engineering - Mechanical	PLS	MH
88.70	Design Engineering - Piping	PLS	MH
88.75	Design Engineering - Process	PLS	MH
88.80	SUB-Design Engineering -Transportation	PLS	MH
88.81	SUB-Design Engineering - Heavy Civil	PLS	MH
88.82	SUB-Design Engineering - Water and Wastewater	PLS	MH
88.83	SUB-Design Engineering - Building	PLS	MH
88.84	SUB-Design Engineering - Power	PLS	MH
88.85	SUB-Design Engineering - Power Delivery	PLS	
88.86	SUB-Design Engineering - Mining	PLS	MH
88.87	SUB-Design Engineering - Food & Beverage	Sht	PLS
88.88	SUB-Design Engineering OGC	PLS	PLS
88.90	SUB-Temp. Structures & Construction Devices (TSCD) Design	PLS	MH
88.95	Design Engineering - Additional Design Services	PLS	MH
88.99	Design Engineering - Specialty and Unique Engineering Work	PLS	MH
90	Construction Equipment	PLS	
90.01	Maintenance	K$	
90.04	Construction Equipment Rent	Wk	
90.06	Equipment Cost Under / Over Allocation	K$	
90.12	Equipment Buy Write-Off Expense (For JV's Only)	PLS	
91	Discipline Services, Tools and Supplies	PLS	
91.01	Man-Hour ST&S	DMH	
91.06	Small Equipment Purchases (<$25,000)	K$	
91.09	District Yard Small Tool and Equipment Management (<$25,000)	K$	Ea
92	Direct Estimated ST&S	PLS	

92.50	Removals and Demolition Direct Estimated ST&S	PLS	
92.51	Grading Direct Estimated ST&S	PLS	
92.52	Civil Utilities Direct Estimated ST&S	PLS	
92.53	Aggregates and Paving Direct Estimated ST&S	PLS	
92.54	Temporary Work	PLS	
92.58	Routine Maintenance Direct Estimated ST&S	PLS	
92.60	Deep Foundations Direct Estimated ST&S	Ea	LF
92.61	Concrete Direct Estimated ST&S	CY	
92.62	Metals Direct Estimated ST&S	Ton	
92.70	Piping Direct Estimated ST&S	LF	
92.71	Mechanical Equipment Direct Estimated ST&S	PLS	
92.72	Water and Wastewater Equipment Direct Estimated ST&S	PLS	
92.73	Startup and Performance Testing Direct Estimated ST&S	PLS	
92.74	Process Insulation Direct Estimated ST&S	PLS	
92.80	Railway Direct Estimated ST&S	TF	
92.81	Electrical, Instrumentation, Transmission and Substation Direct Estimated ST&S	LF	
92.82	Waterway and Marine Construction Direct Estimated ST&S	PLS	
92.83	Building Direct Estimated ST&S	PLS	
92.84	Offshore Fabrication Direct Estimated ST&S	PLS	
92.85	Tunneling / Underground Direct Estimated ST&S	PLS	
92.86	Mining Direct Estimated ST&S	PLS	
92.87	Misc Specialty Work Direct Estimated ST&S	PLS	
92.88	Design Engineering Direct Estimated ST&S	PLS	
93	Bulk Commodities	PLS	
93.50	Removals and Demolition Bulk Commodities	PLS	
93.51	Grading Bulk Commodities	PLS	
93.52	Civil Utilities Bulk Commodities	PLS	
93.53	Aggregates and Paving Bulk Commodities	PLS	
93.58	Routine Maintenance Bulk Commodities	PLS	
93.60	Deep Foundations Bulk Commodities	LF	Ea
93.61	Concrete Bulk Commodities	CY	
93.62	Metals Bulk Commodities	Ton	
93.70	Piping	LF	
93.71	Mechanical Equipment Bulk Commodities	PLS	
93.72	Water and Wastewater Equipment Bulk Commodities	PLS	
93.73	Startup and Performance Testing Bulk Commodities	PLS	
93.74	Process Insulation Bulk Commodities	PLS	
93.80	Railway Bulk Commodities	TF	

93.81	Electrical, Instrumentation, Transmission and Substation Bulk Commodities	PLS	
93.82	Waterway and Marine Construction Bulk Commodities	PLS	
93.83	Building Bulk Commodities	PLS	
93.84	Offshore Fabrication Bulk Commodities	PLS	
93.85	Tunneling / Underground Bulk Commodities	LF	CY
93.86	Mining Bulk Commodities	PLS	
93.87	Misc Specialty Work Bulk Commodities	PLS	
94	Engineered Equipment	PLS	
94.03	Energy Engineered Equipment	PLS	
94.80	Railway Engineered Equipment	PLS	
95	Subcontracts	PLS	
95.50	Removals and Demolition Subcontracts	PLS	
95.51	Grading Subcontracts	PLS	
95.52	Civil Utilities Subcontracts	PLS	
95.53	Aggregates and Paving Subcontracts	PLS	
95.54	Temporary Work	PLS	
95.58	Routine Maintenance Subcontracts	PLS	
95.60	Deep Foundations Subcontracts	Ea	LF
95.61	Concrete Subcontracts	CY	
95.62	Metals Subcontracts	Ton	
95.70	Piping Subcontracts	LF	
95.71	Mechanical Equipment Subcontracts	PLS	
95.72	Water and Wastewater Equipment Subcontracts	PLS	
95.73	Startup and Performance Testing Subcontracts	PLS	
95.74	Process Insulation Subcontracts	PLS	
95.80	Railway Subcontracts	TF	
95.81	Electrical, Instrumentation, Transmission and Substation Subcontracts	LF	
95.82	Waterway and Marine Construction Subcontracts	PLS	
95.83	Building Subcontracts	BGSF	
95.84	Offshore Fabrication Subcontracts	PLS	
95.85	Tunneling / Underground Subcontracts	PLS	
95.86	Mining Subcontracts	PLS	
95.87	Misc Specialty Work Subcontracts	PLS	
99	Change Orders, Contract Allowances and Back charges	PLS	
99.03	Owner Allowances	PLS	
99.06	Change Orders	PLS	
99.09	Back charges	PLS	
99.49	Quantity Metrics - Overall Jobsite	PLS	

99.51	Quantity Metrics - Grading	PLS	
99.52	Quantity Metrics - Civil Utilities	PLS	
99.53	Quantity Metrics - Aggregates and Paving	PLS	
99.54	Quantity Metrics - Temporary Work	PLS	
99.60	Quantity Metrics - Deep Foundations	PLS	
99.61	Quantity Metrics - Concrete	CY	
99.62	Quantity Metrics - Metals	PLS	
99.80	Quantity Metrics - Railway	PLS	
99.83	Quantity Metrics - Building	BGSF	
99.90	Quantity Tracking to Support Metrics / Ratios - Energy	PLS	
99.91	Quantity Tracking to Support Metrics / Ratios - OGC	PLS	
99.99	Transitional Account Code	PLS	

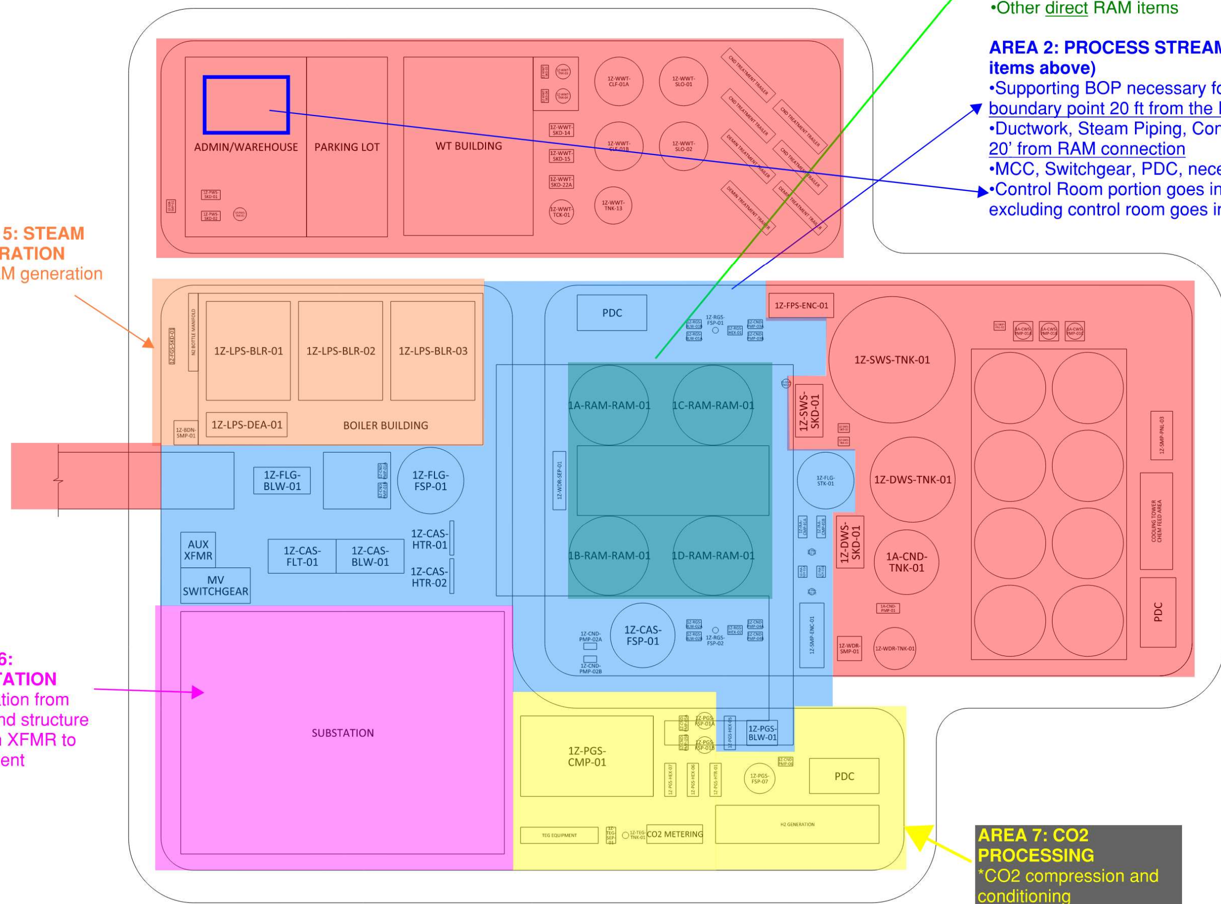
APPENDIX 2: LAFARGEHOLCIM COST AREA MAP

AREA MAP FOR HOLCIM, CO -
4750 TPD CO_2 CAPTURE - CEMENT PLANT

AREA 1: RAM
- RAM Components, gear drive, RAM electrical & control panels
- RAM Foundation,
- RAM Structural Steel, RAM Platforms
- Other direct RAM items

AREA 2: PROCESS STREAM BOP (excludes cost bucket #1 RAM items above)
- Supporting BOP necessary for the RAM to function – taken to a boundary point 20 ft from the RAM
- Ductwork, Steam Piping, Conditioning Air, Utilities, Supports - out to 20' from RAM connection
- MCC, Switchgear, PDC, necessary to make the Capture Plant run
- Control Room portion goes into this cost bucket. Admin building excluding control room goes into cost bucket 4.

AREA 5: STEAM GENERATION
*STEAM generation



AREA 3: ADDITIONAL SITE BOP (BOP that is unique and required due to the specific site location or client requirements)
- Additional Ductwork, Steam Piping, Conditioning Air, Supports, Utilities (gas, water, air, electrical) – from 20' to actual connection. (Example: the 980' of flue gas ductwork and support steel to get from the RAM boundary over to the connection point at the cement plant)
- Water Treatment
- Tanks
- Cooling Tower
- Fire Protection, loops and equipment

AREA 4: SITE INFRASTRUCTURE:
- Earthworks (cut/fill)
- Piles (if required)
- Roads, Drainage,
- Improvements (fences, security, lighting)
- Admin Building/Warehouse/parking lot (Excluding control room)

AREA 6: SUBSTATION
*substation from dead end structure through XFMR to equipment

AREA 7: CO2 PROCESSING
*CO2 compression and conditioning

30 0 30 60
SCALE IN FEET
SCALE: 1" = 30'-0"

- PRELIMINARY -
NOT FOR CONSTRUCTION

REV		DESIGN BY	CHECKED BY	DATE
A	Issued for information	S. Sunby	—	OPEN

SVANTE
LAFARGE CO2 CAPTURE

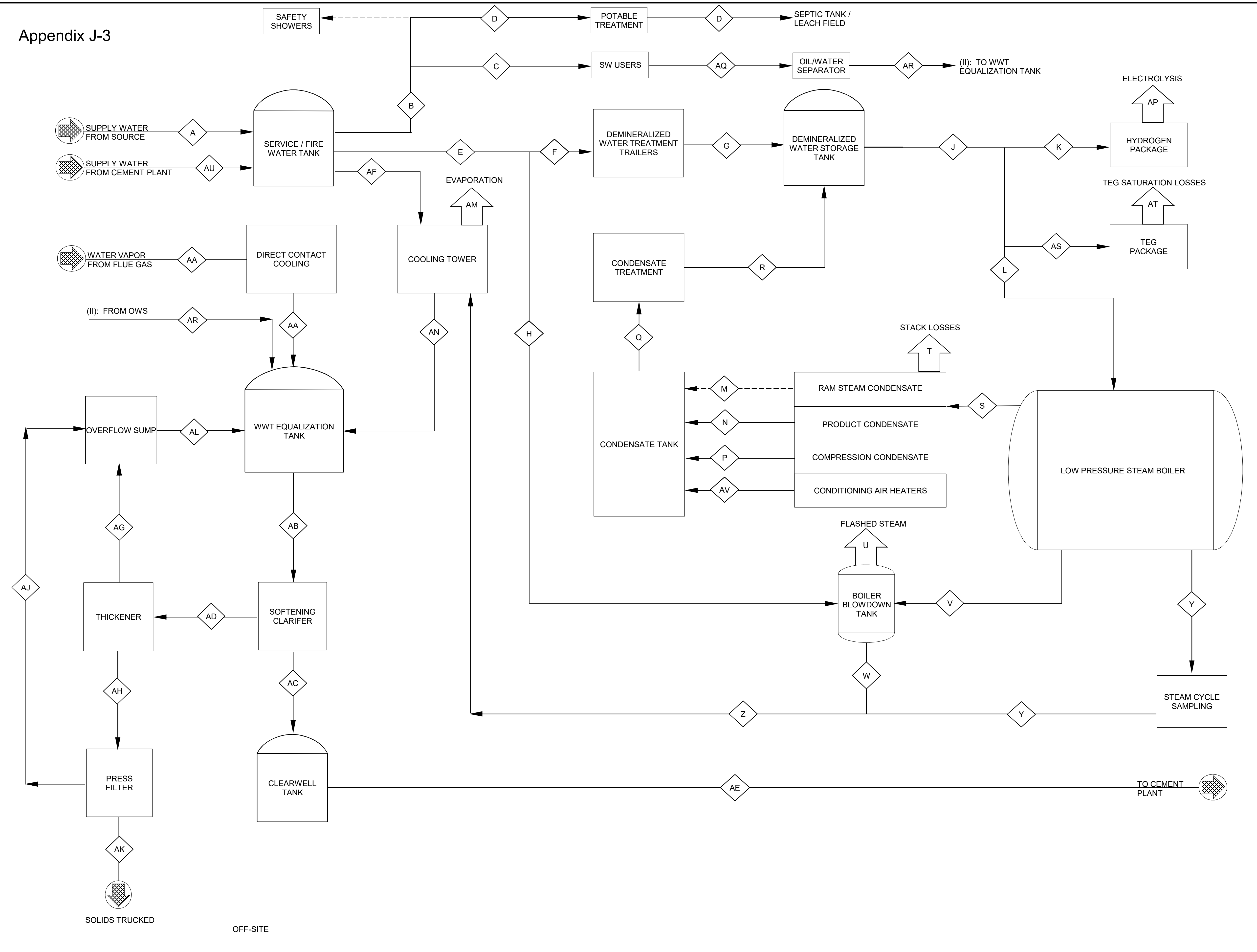
Svante
Kiewit

PLOT PLAN OPTION 2

ENGINEER/DESIGN ORIGINATOR	S. Sunby
LEAD ENG	K. SATROM
ENG MGR	R. McLandsborough
PROJ MGR	N. ROBINSON

DRAWING NUMBER
20035944-PP-001

Appendix J-3



NOTES

1. ACTUAL PIPE ROUTING AND PROCESS FLOW LOCATIONS SUBJECT TO CHANGE
2. LARGE ARROWS DESIGNATE STREAMS ENTERING / EXITING THE PROJECT BOUNDARY LIMITS.
3. DASHED LINES REPRESENT "NORMALLY NO FLOW" (NNF) CONDITION.
4. EQUIPMENT SELECTION AND SIZING SUBJECTO CHANGE BASED ON FUTURE INFORMATION.

- PRELIMINARY -
NOT FOR CONSTRUCTION / PERMITTING

REV			
B	ISSUED FOR REPORT		
	C. STATLER		03/14/22
A	ISSUED FOR INFORMATION		
	C. STATLER		11/12/21
REV	DESIGN BY	CHECKED BY	DATE

SVANTE
LAFARGE CO2 CAPTURE - FEL 2
MAX COOLING TOWER, FULL RECYCLE, WATER TRADE

VELOXOTHERM - 4750 TPD

Kiewit

WATER MASS BALANCE
PROCESS FLOW DIAGRAM

ORIGINATOR: C. STATLER
DRAWING NUMBER: 20035944-WMB-00