Final Report

VeloxoTherm™ CO_2 Capture Project

Prepared For:	Emissions Reduction Alberta (ERA) – (ne CCEMC)
Agreement #:	H110061
Date:	October 21, 2021
Classification:	Non-Confidential Project Final Report

Prepared by:

Svante Inc.
8528 Glenlyon Parkway, Unit 142
Burnaby, BC Canada V5J 0B6
www.svanteinc.com

This document entitled, *VeloxoTherm™ CO2 Capture Project* was prepared by Svante. The material in it reflects Svante's best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Svante accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

Revision History

REV	DCN	STATUS	AUTHORED/REVISED BY DATE	APPROVED BY DATE
1	INV009-0000-RPT-ERA002	IFI	Matt Stevenson 2021-10-21	Matt Stevenson 2021-10-21

Glossary

0.5TPD Demo Plant	Field testing unit deployed to Husky Lashburn site for actual flue gas testing at 0.5 tonne/day scale
30TPD Pilot Plant	The main objective of the ERA Project, industrially relevant pilot-scale VeloxoTherm™ capture plant at Husky Lashburn site
Beds	Means "structured adsorbent" beds – used interchangeably with "SAB"
ERA Project	Refers to project described by contribution agreement H110061 between Svante and ERA; generally refers to the entire project/program described herein
First Phase – Early Development	The early development phase of the ERA Project, from its inception on April 1, 2012 through November, 2016.
FOAK 400 Series	First-a-kind ~4m nominal diameter rotary adsorption machine as specified for the 30TPD Pilot Plant
Gen I SAB	Generation I SAB means first generation SAB
Gen II SAB	Generation II SAB means second generation SAB
Gen III SAB	Similar to Gen II SAB, but with improvements to active materials
Gen III½ SAB	Same as Gen III SAB, but with improved SAB bed mechanical and thermal design
Gen IV SAB	Generation IV SAB means laminated structured adsorbent beds using the more advanced adsorbent family
Husky Energy	Means Husky Energy Inc., Husky Oil Operations Limited, and, after January 4th, 2021, affiliates of Cenovus Energy Inc.
Mark I	Discontinued reference to single-adsorbent SAB architectures
Mark II	Discontinued reference to multi-adsorbent SAB architectures
PPCU	Pilot Plant Capture Unit, used interchangeably with 30TPD Pilot Plant
Second Phase – SAB Development and Field Testing	The Second Phase of the ERA Project scope, beginning in November, 2016 and continuing through June, 2017
Series 1 SAB	First series of SAB tested at 0.5TPD Demo Plant - Gen III½ SAB
Series 2 SAB	First series of advanced sorbnet SAB developed and field tested
Series 3 SAB	Improved series of advanced sorbent SAB as tested in both the 0.5TPD Demo Plant, and as the first set of SABs tested in the 30TPD Pilot Plant
Series 4 SAB	SAB series incorporating additional improvements over S3 SABs in terms of adsorbent resilience – tested on the 30TPD Pilot Plant after the technical completion of the ERA Project
Sorbent	Means the raw active solid material which effects the separation of CO_2 from other gases – used interchangeably and equivalently with "adsorbent"
Svante	Means Svante Inc, previously called Inventys Thermal Technologies Inc.
Third Phase – 30TPD Pilot Plant Execution	The Third Phase of the ERA Project, from June 2017 to August 2020 comprising the full execution of the 30TPD Pilot Plant

Acronyms and Abbreviations

BFD	Block Flow Diagram
BFW	Boiler Feedwater

CSU	Commissioning Services Unit
DBM	Design Basis Memorandum
DCS	Distributed Control System
DFMEA	Design Failure Modes and Effects Analysis
DOR	Division of Responsibility
DVPR	Design Verification Plan and Report
ERA	Emissions Reduction Alberta
EPC	Engineering, Procurement and Construction
FAT	Factory Acceptance Testing
FEED	Front End Engineering and Design
FEL	Front End Loading
FOAK	First-of-a-kind
GHG	Greenhouse Gas
HAZOP	Process hazards and operability analysis
HSSE	Health, Safety, Security and Environment
HVAC	Heat, Ventilation and Air Conditioning
IFC	Issued for Construction
KPI	Key Performance Indicator
LOPA	Layers of protection analysis
PDU	Process Demonstration Unit
PFD	Process Flow Diagram
P&ID	Piping and Instrumentation Diagram
PLC	Programmable Logic Computer
QA	Quality Assurance
QC	Quality Control
RACI	Responsibility assignment matrix (responsible, accountable, consulted, informed)
RAM	Rotary Adsorption Machine
S1	Series 1 (adsorbent, see glossary)
S2	Series 2 (adsorbent, see glossary)
S3	Series 3 (adsorbent, see glossary)
S4	Series 4 (adsorbent, see glossary)
SAB	Structured Adsorbent Bed
TPD	Tonnes per day (typically referring to CO_2)
TRL	Technology Readiness Level
UPS	Universal Power Supply
VTS	Variable Test Station

Table of Contents

Glossary 3

Acronyms and Abbreviations 3

1. Project Description 7

1.1 Technology Description 7

1.2 Project Objectives 8

1.3 Work Scope Overview 9

1.4 Results and Performance 11

2. Project Overview & Outcomes 13

2.1 First Phase – Early Development 13

2.1.1 0.5TPD Demo Plant Development 13

2.2 Second Phase – SAB Development and Field-Testing 14

2.2.1 SAB Manufacturing 14

2.2.2 0.5TPD Demo Plant Testing 15

2.3 Third Phase – 30TPD Pilot Plant Execution 15

2.3.1 Front End Engineering and Design 16

2.3.2 30TPD Pilot Plant RAM Fabrication and SAB Production 17

2.3.3 Execution, Construction and Installation 18

3. Lessons Learned 20

3.1 Technology & Product Roadmap 20

3.2 Project Execution 20

4. Market and Commercialization Plan 21

Tables:

Table 1: Technology Readiness Level Definitions 12
Table 2: FEED and Detailed Engineering Key Deliverables 16

Figures:

Figure 1: Schematic of Svante's Core CO_2 Capture Technology (VeloxoTherm™) 7
Figure 2: ERA Project Timeline - Phases & Milestones 10
Figure 3: ERA Project Impact on Technology Readiness Levels 11
Figure 4: 0.5TPD Demo Plant at Svante Facilities 13
Figure 5: 0.5TPD Demo Plant installed at Husky Energy Lashburn operating site 14
Figure 6: Major Equipment Purchased for SAB Manufacturing Line 15
Figure 7: SAB Manufacturing Plant Layout 15
Figure 8: 30TPD Pilot Plant Execution Timeline 16
Figure 9: 400 Series RAM - (LHS) Concept Design c.a. 2017 - (RHS) FAT at Arvos Facility, November 2018 17
Figure 10: First set of 30TPD Pilot Plant scale structured adsorbent beds (S3, PEIDS) as at April, 2019 ... 18
Figure 11: 30TPD Pilot Plant Construction Timeline Highlights 19

1. Project Description

Svante Inc. (“Svante”, formerly Inventys Thermal Technologies Inc.) has been developing an advanced CO_2 capture technology since 2007. The technology approach (VeloxoTherm™) relies on the use of structured solid adsorbents and intensified adsorption process cycles to deliver a significant reduction in capital costs and total capture costs relative to the current state-of-the-art approaches. The project described herein, as funded under contribution agreement H110061 with ERA (the “ERA Project”), was intended to result in the demonstration of this VeloxoTherm™ technology in an operating pilot plant at an oil and gas facility in western Canada, and at an industrially relevant scale.

In order to achieve this however, there were a number of other activities included within the ERA Project, including the development and optimization of adsorbent materials and architectures, scale-up of manufacturing processes and mechanical designs, and small-scale field testing and trialing of the technology. As a result, the ERA Project comprises a period from 2012 until 2020 which is coincident with the bulk of Svante’s technology development from early proof of concept until the current stage of product commercialization and business scale-up.

Svante initially contracted with ERA for the project in September, 2012 and over a significant number of subsequent amendments, the scope and timeline of the project grew substantially over an almost 8 year period of performance. This stands as further evidence of the dynamic and challenging nature of bringing a fundamentally new industrial process technology from laboratory proof of concept to a significant field demonstration. ERA’s flexibility and support through this program, however, were instrumental in Svante and the project ultimately succeeding in demonstrating a world-first VeloxoTherm™ CO_2 capture plant on an operating energy facility in western Canada; a remarkable achievement for all stakeholders.

1.1 Technology Description

Svante’s VeloxoTherm™ technology captures carbon dioxide from flue gas or stack gas point-sources, and purifies it for safe storage or industrial use. The approach is tailored specifically to the challenges of separating CO_2 from nitrogen contained in flue gases or emissions generated by industrial plants such as boilers, heaters, cement kilns, steel plants, petrochemicals and hydrogen; typically emitted in large volumes, at low pressures, and dilute concentrations. Svante’s second-generation technology integrates high performance sorbents (high CO2 capacity, high surface to volume ratio, fast kinetics and tolerance to impurities), novel structured adsorbent architecture (to achieve high heat and mass transfer rates) and process intensification (rapid cycle TSA) in a single piece of equipment to capture and release CO2.

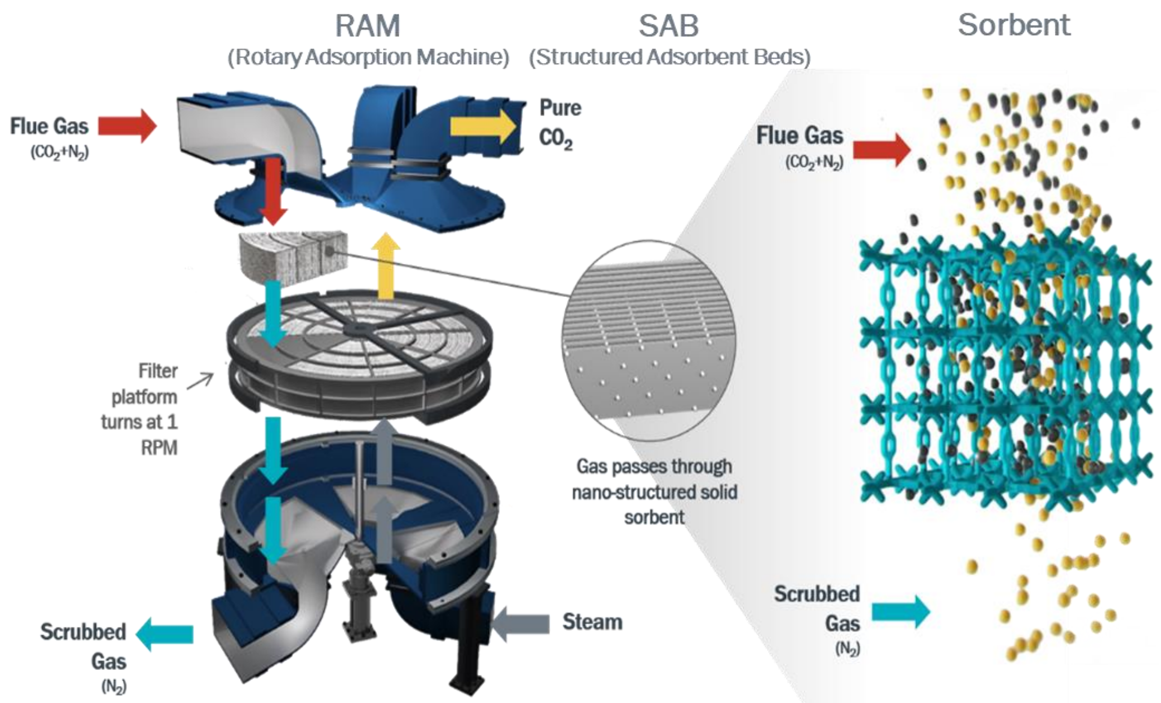

Figure 1: Schematic of Svante's Core CO_2 Capture Technology (VeloxoTherm™)

Conventional pressure swing adsorption processes are not well-suited to atmospheric post-combustion CO_2 capture due to the energy required to compress the large volume of gases. Conventional temperature swing adsorption processes, meanwhile, are hampered by poor heat and mass transfer properties and result in prohibitively long cycle times and large equipment costs. The VeloxoTherm™ process developed by Svante is comprised of a rapid cycle thermal swing adsorption (TSA) process that uses a patented architecture of Structured Adsorbent Beds (SAB) and a novel process design and embodiment to capture CO2 from industrial and natural gas-fired flue gas streams. SABs possess unique physical and transport properties which serve to greatly improve the performance of gas separation, enabling fast cycle times and small equipment sizes that deliver attractive capture economics.

The Svante VeloxoTherm™ process consists of a series of process steps which pass flue gas, regenerating steam and conditioning air through the SABs in a specific order.

- **Adsorption:** The first step in the process is the introduction of the feed gas into the SAB, where CO2 is adsorbed onto the adsorbent and the remainder of the flue gas (N2, O2 and H2O) is sent to the stack.
- **Regeneration:** The CO2-rich SAB then rotates to a sector of the process where low pressure steam flows through the SAB. Steam regenerates the SAB, releasing a stream of primarily CO2 and steam (product
- **Conditioning:** After regeneration with steam, the RAM rotates through a sector where gas streams condition and cool the SAB.

1.2 Project Objectives

The primary objective of this project was for Svante to design, manufacture, and install a VeloxoTherm™ CO_2 capture pilot plant at Husky's EOR facility in Lashburn Saskatchewan. While there was considerable evolution and iteration of the final design basis of this pilot plant, the final selected maximum capacity arrived at was 30 tonnes/day of CO_2 captured (30 TPD).

The ERA project was segmented into two major sets of activities: 1) optimization and performance validation of the VeloxoTherm™ structured sorbent and 2) design, fabrication, installation and testing of the 30 tonne/day CO_2 pilot plant itself. In addition, supporting both of these areas of activity, was significant scale-up activity with respect to SAB manufacturing processes and capability, as well as adsorption machine (RAM) design. Throughout the ERA Project, risk mitigation efforts included significant front-end loading and component-level de-risking/validation for critical items such as adsorbent beds, seals, process cycle, overall plant design, etc. When of the key tools used in this regard was the 0.5TPD Demo Plant, operated at the actual Husky Lashburn site for performance validation on the same flue gas as the 30TPD Pilot Plant.

Svante met the ultimate project objective by successfully commissioning and testing the 30TPD Pilot Plant in 2020, achieving performance results in line with or better than agreed targets per the Husky Large Pilot Host Site Agreement. Svante continues to operate this plant today to gather additional operating data and inform further optimization and development of the technology. In order achieve this overall result, a large set of development, scale-up, testing and optimization efforts were required over the more than 8 year overall period of performance, and this is reflected by the evolution of the ERA Project scope and Contribution Agreement Amendments required to achieve the Project Objectives.

1.3 Work Scope Overview

In addition to the design, fabrication, installation and testing of the 30TPD Pilot Plant itself, the ERA Project comprised a significant portion of activities to address performance validation and improvement of the structured adsorbent beds, scale-up of manufacturing capability, and small-scale demonstration and prototyping activities to assist in readying the technology for the pilot plant phase.

In order to assist in understanding the different segments of work performed during the ERA Project, it is helpful to consider three informal phases:

- **First Phase – Early Development:** The early development phase of the ERA Project, from its inception on April 1, 2012 through November, 2016,
- **Second Phase – SAB Development and Field-Testing:** The Second Phase of the ERA Project scope, beginning in November, 2016 and continuing through June, 2017, focused on continued SAB development and optimization, scale-up of SAB manufacturing to pilot scale, field testing of the technology in the 0.5TPD Demo Plant, and early engineering on the 30TPD Pilot Plant
- **Third Phase – 30TPD Pilot Plant Execution:** The Third Phase, from June 2017 to August 2020 comprised the full detailed design, procurement, fabrication, installation, construction, commissioning and testing cycle for the 30TPD Pilot Plant

	Start	End
Phase One: Early Development		
Milestone 1	01/Apr/12	31/Oct/12
Milestone 2	01/Nov/12	15/Jun/13
Milestone 3	01/May/13	29/Nov/13
Milestone 4	02/Dec/13	13/Feb/15
Milestone 5	01/Sep/14	30/Apr/15
Milestone 6	01/May/14	30/Oct/15
Milestone 7	02/Mar/15	30/Nov/16
Phase Two: SAB Development and Field-Testing		
Milestone 8	01/Nov/16	31/Dec/16
Milestone 9	01/Jan/17	30/Sep/17
Phase Three: 30TPD Pilot Plant Execution		
Milestone 10	01/Jun/17	30/Oct/18
Milestone 11	01/Sep/17	31/Mar/20
Milestone 12	15/Apr/20	31/Aug/20

Figure 2: ERA Project Timeline - Phases & Milestones

1.4 Results and Performance

The most important achievement of this ERA Project, was the successful commissioning and operation of the 30TPD Pilot Plant, which achieved a daily CO_2 production rate of 30 tonnes/day on January 22, 2020. This fundamentally increased the technology readiness level of Svante's VeloxoTherm™ CO_2 capture technology, and has enabled Svante to subsequently move into the commercialization phase of its development and develop an aggressive go-to-market strategy for the technology. Figure 3 highlights the progression of technology readiness level of the VeloxoTherm™ technology from the start of the ERA Project in 2012, through to its completion in 2020 (see Table 1 for a detailed explanation of each TRL).

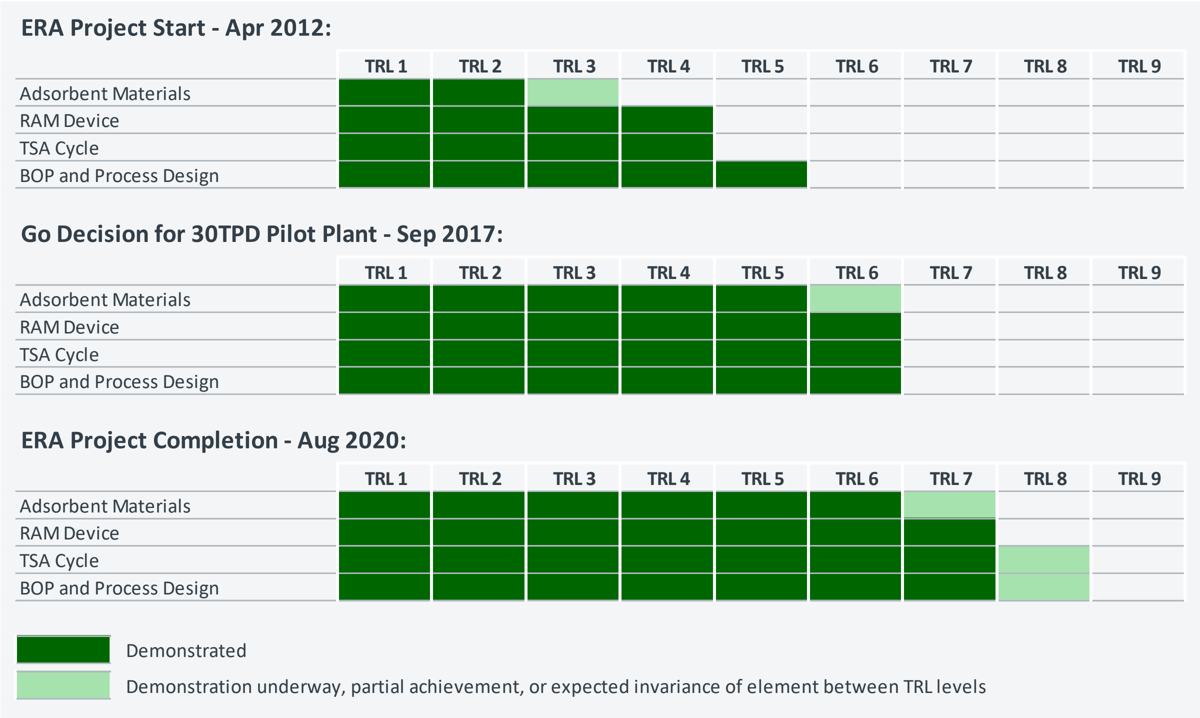

Figure 3: ERA Project Impact on Technology Readiness Levels

Table 1: Technology Readiness Level Definitions

TRL 1—Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.
TRL 2—Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions.
TRL 3—Analytical and experimental critical function and/or characteristic proof of concept	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology.
TRL 4—Product and/or process validation in laboratory environment	Basic technological products and/or processes are tested to establish that they will work.
TRL 5—Product and/or process validation in relevant environment	Reliability of product and/or process innovation increases significantly. The basic products and/or processes are integrated so they can be tested in a simulated environment.
TRL 6—Product and/or process prototype demonstration in a relevant environment	Prototypes are tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a simulated operational environment.
TRL 7—Product and/or process prototype demonstration in an operational environment	Prototype near or at planned operational system and requires demonstration of an actual prototype in an operational environment (e.g. in a vehicle).
TRL 8—Actual product and/or process completed and qualified through test and demonstration	Innovation has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development.
TRL 9—Actual product and/or process proven successful	Actual application of the product and/or process innovation in its final form or function.

2. Project Overview & Outcomes

As introduced previously, the ERA Project comprised almost 8 years, with significant modification throughout; as such, it is helpful to segment the overall project into three different phases: "First Phase – Early Development", "Second Phase – SAB Development and Field-Testing", and "Third Phase – 30TPD Pilot Plant Execution". The following considers the activities and outcomes of the ERA Project segmented into those three phases.

2.1 First Phase – Early Development

The early development phase of the ERA Project, from its inception on April 1, 2012 through November, 2016, also comprised the early stages of maturing the VeloxoTherm™ technology from the initial proof-of-concept and bench scale, through to a technology ready for field testing and further development towards the final goal of the 30TPD Pilot Plant. The general activities undertaken during this first phase include Milestones 1 through 7 of the ERA Work Plan, culminating in the successful go/no-go decision by Svante, Husky Energy, ERA, and other project stakeholders and funding bodies to move ahead with the FEED and execution of the 30TPD Pilot Plant project.

2.1.1 0.5TPD Demo Plant Development

In order to de-risk the design of the 30TPD Pilot Plant and enable a go/no-go decision on the execution and construction of the larger plant, Svante and Husky Energy arranged to upgrade, retrofit and reconfigure an existing ~0.5TPD field demonstration plant and ship it to the Lashburn site to operate on the same flue gas as the 30TPD Pilot Plant would process. This enabled the testing of multiple iterations of adsorbent/SAB generations and processes prior to freezing the design for the 30TPD Pilot Plant and was a key contributor to achieving a successful "go" decision on the larger pilot plant from Husky Energy and the project funding partners.

Figure 4: 0.5TPD Demo Plant at Svante Facilities

Figure 4 above shows the 0.5TPD Demo Plant after completion of the initial upgrading and retrofit at Svante's facilities in Burnaby, prior to shipping to the Lashburn Husky site in Saskatchewan. As at the completion of Milestone 7, and the First Phase of the ERA Project, this 0.5TPD Demo Plant was fully installed at the Husky Site with Gen III½ activated carbon "commissioning" beds, and had successfully passed a post-construction review and walkthrough by Husky Personnel – commissioning began during the Second Phase of the ERA Project as described below. Figure 5 below illustrate the installed 0.5TPD Demo Plant at the Husky Lashburn site, within its tent enclosure.

Figure 5: 0.5TPD Demo Plant installed at Husky Energy Lashburn operating site

2.2 Second Phase – SAB Development and Field-Testing

The Second Phase of the ERA Project scope, beginning in November, 2016 and continuing through September, 2017 spans activities which include ERA Project Milestones 8 and 9. This phase built on the decisions made in 2016 (towards the end of “Early Development” phase per above), being primarily the decision to move the project forward with more advanced adsorbent materials than Gen I through III adsorbents. At the beginning of the Second Phase of the ERA Project, an advanced sorbent family was selected for critical path development, optimization, testing in the 0.5TPD Demo Unit, and specification for the 30TPD Pilot Plant early designs. Alongside this continued SAB development/optimization and field testing, the Second Phase also comprised the scale-up of SAB manufacturing to prepare for pilot-plant scale production.

2.2.1 SAB Manufacturing

During the early stages of the ERA Project, Svante developed the ability produce laminated structured adsorbent beds (ie. “Gen II” architecture) for its in-house test stations (VTS and PDU) as well as the 0.5TPD Demo Plant. The 30TPD Pilot Plant, however, represented an order of magnitude increase in the scale and volume of SABs that would be required. A major deliverable of the ERA Project was the development, design, acquisition, installation and commissioning of a full pilot-scale SAB manufacturing line at Svante’s facilities in Burnaby, BC.

During the First Phase of the ERA Project, Svante had also acquired certain long-lead major equipment items for the pilot-scale SAB Manufacturing line, including a Faustel Coating line, Rotary Screen Printer, and laminate sheet stacking robot. This equipment is illustrated in Figure 6.

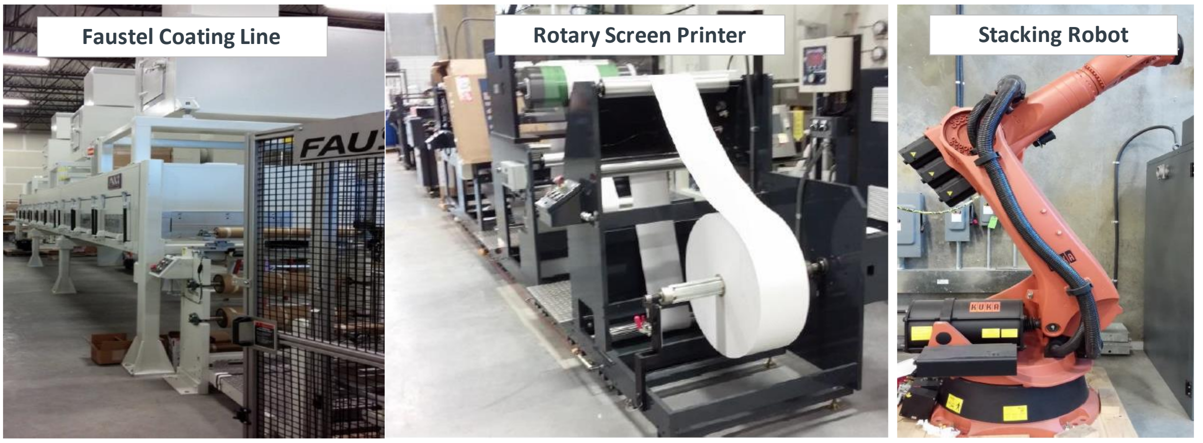

Figure 6: Major Equipment Purchased for SAB Manufacturing Line

The layout of this SAB manufacturing equipment was as provided in Figure 7 below.

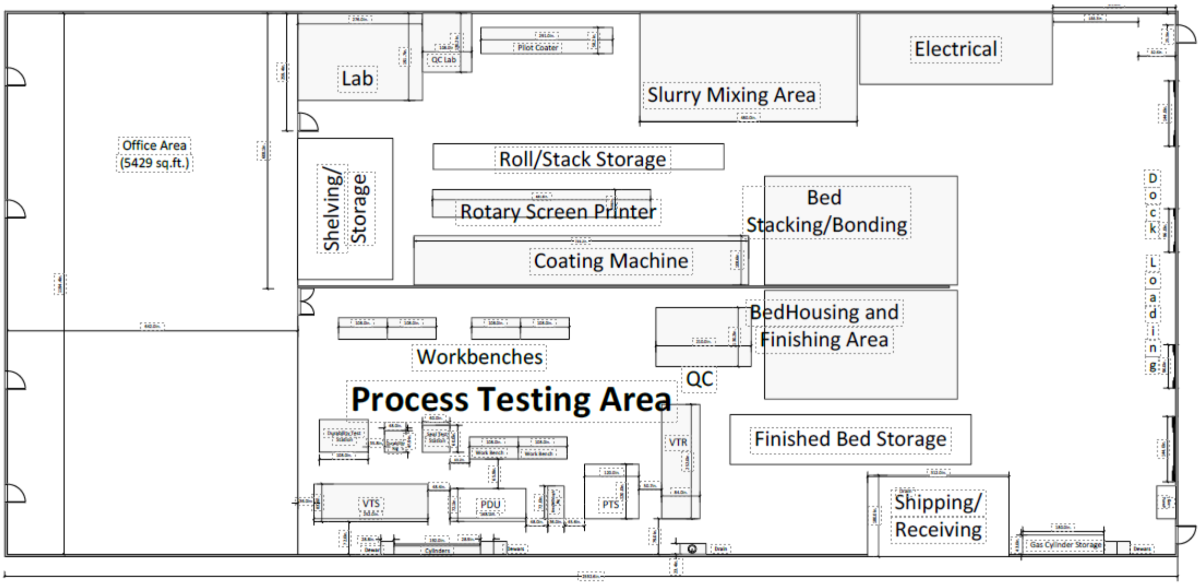

Figure 7: SAB Manufacturing Plant Layout

2.2.2 0.5TPD Demo Plant Testing

The 0.5TPD Demo Plant was upgraded, retrofitted, shipped and installed at Husky's Lashburn site as part of Milestone 7 in the First Phase of the ERA Project. During the Second Phase, the 0.5TPD Demo Plant was fully commissioned on actual flue gas, initially using the Series 1 (S1) or "Gen III½" SABs. The S1 beds were intended as commissioning beds only, and were not intended to meet any program performance targets. In June, 2017, the first set of PEIDS based SABs were installed in the 0.5TPD Demo Plant, and testing began in July, 2017.

2.3 Third Phase – 30TPD Pilot Plant Execution

The Third Phase of the ERA Project – "30TPD Pilot Plant Execution" comprises the completion of milestones 10, 11 and 12, and includes the completion of FEED, detailed design, procurement, fabrication, installation, construction, commissioning and testing for the 30TPD Pilot Plant. This set of activities consumed the largest portion of the overall project budget, and occurs over the period from June, 2017, until the ERA

Project's completion in August, 2020 (although certain early FEED activities were initially worked on in prior phases). Figure 8 shows the overall execution timeline for the 30TPD Pilot Plant, on an as-built basis.

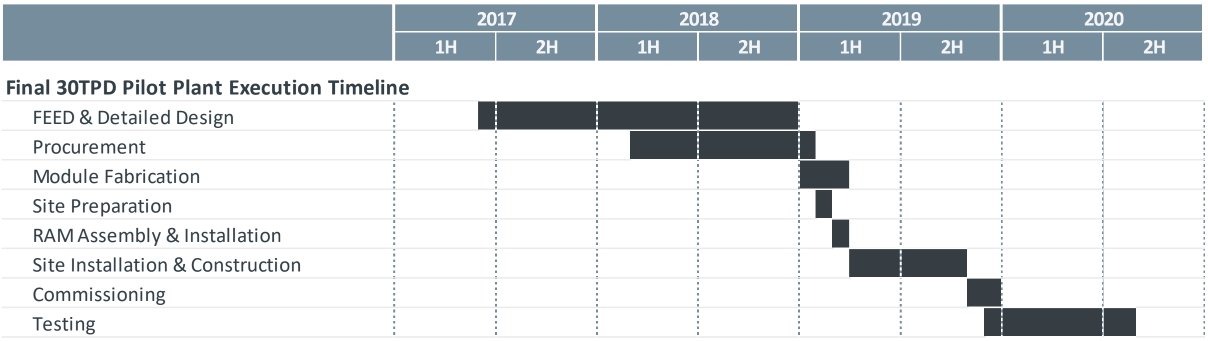

Figure 8: 30TPD Pilot Plant Execution Timeline

2.3.1 Front End Engineering and Design

Front End Engineering and Design ("FEED") and detailed engineering for the 30TPD Pilot Plant were performed with significant overlap in order to mitigate delays in the overall project schedule through parallel path efforts. The initial conceptual FEED activities began in June, 2017 with the development of the first revisions of the Design Basis Memorandum ("DBM"), Block Flow Diagrams ("BFD"s), and Process Flow Diagrams ("PFD"s) completed prior to the formal kick-off of the 30TPD Pilot Plant project on October 2nd, 2017. On September 15, 2017, the engineering contract for 3rd party FEED and detailed engineering services was awarded and efforts commenced to complete full FEED and detailed engineering. The primary deliverables for both FEED and detailed engineering are highlighted in Table 2 below.

Table 2: FEED and Detailed Engineering Key Deliverables

Item	Addressed during FEED	Final Completion (IFC)
Design Basis Memorandum	Yes	16-November-2017
Block Flow Diagram	Yes	16-November-2017
Process Flow Diagrams	Yes	16-November-2017
Heat & Material Balance	Yes	16-November-2017
Major Equipment List	Yes	16-November-2017
Piping & Instrumentation Diagrams	Partial	1-June-2018
HAZOP	Yes	25-April-2018
Process Control Philosophy	Partial	16-November-2017
Plant and Facilities Layout	Yes	16-November-2017
3D Model & General Arrangement	Partial	2-November-2018
Process Equipment Data Sheets	Partial	1-June-2018
Equipment Sizing & Specification	Partial	1-June-2018
Piping Line List with Specifications	Partial	1-June-2018
Piping Isometric Drawings	No	2-November-2018
Structural and Module Design	No	31-January-2019
Civil - Subsoil Investigation	Partial	
Civil - Site Preparation Requirements	Partial	1-June-2018
Civil & Structural Design Criteria	No	1-June-2018
Module Foundation Design	No	1-June-2018
Pipe Rack Foundation Design	No	1-June-2018
Electrical Design Basis & Load List	Partial	16-September 2019
Electrical Single-Line Drawings	No	16-September 2019

Instrument Lists and Data Sheets	Partial	16-September 2019
Instrumentation & Controls Detailed Design	No	16-September 2019
Control Narratives	Partial	16-September 2019
Control Valve Sizing	Partial	1-June-2018
I/O List	No	16-September 2019
PSV list and Discharge points	Partial	1-June-2018
Facilities and Building Design	Partial	1-June-2018
HVAC Design	No	1-June-2018
Gas & Fire Detection & Protection Design	Partial	1-June-2018

2.3.2 30TPD Pilot Plant RAM Fabrication and SAB Production

A successful go/no-go decision was received by Svante from Husky Energy in January of 2018, allowing the Company to proceed with long-lead critical path items for delivering the 30TPD Pilot Plant. Among the most important items were the kick-off of the fabrication of the Rotary Adsorption Machine (RAM), and the procurement and production initiation of the initial sets of SABs for the 30TPD Pilot Plant.

Svante selected the Arvos Group for fabrication of the RAM designed for the 30TPD Pilot Plant, known as the 400 Series RAM (nominal ~4m diameter). In March of 2018, Arvos kicked-off fabrication of the 400 Series RAM at their fabrication facilities in Wellsville, New York. The 400 Series RAM completed factory acceptance testing at Arvos' facility in November, 2018 and Figure 9 shows the result of the FAT alongside the initial machine concept design.

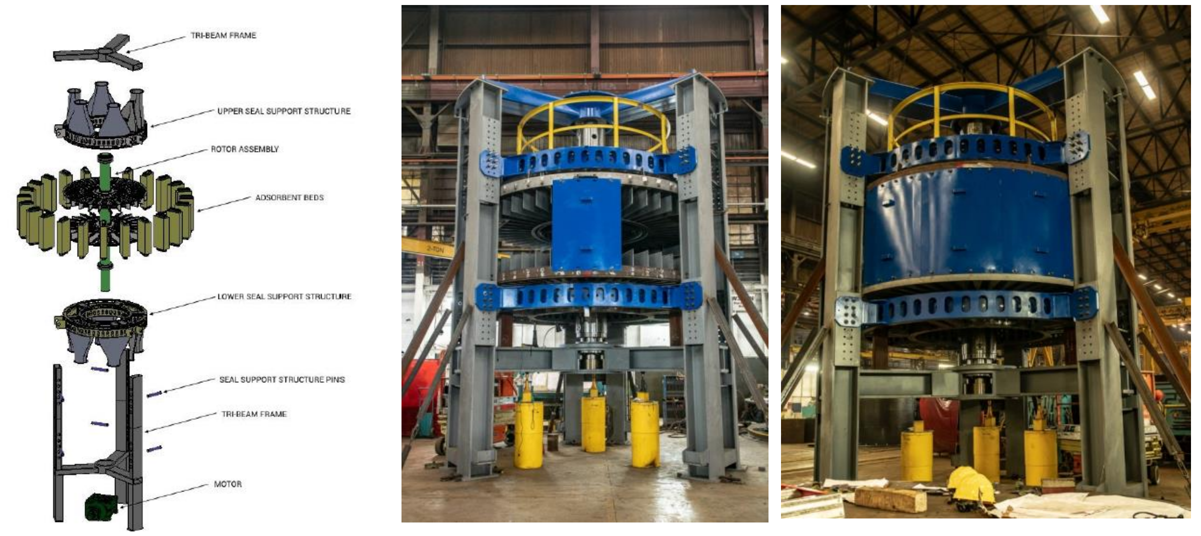

Figure 9: 400 Series RAM - (LHS) Concept Design c.a. 2017 - (RHS) FAT at Arvos Facility, November 2018

In order to produce the volumes of sorbent required for the 30TPD Pilot Plant SABs, Svante worked with a manufacturing partner for synthesis of the advanced sorbent powder (Series 3 generation for the initial set of SABs for the 30TPD Pilot Plant). Svante received more than 2,000kg of advanced adsorbent powder from this partner in 2018. This level of production represented an order of magnitude increase in the production level for raw sorbent powder achieved by Svante, and represented a successful implementation of rapid innovation, technology transfer and open collaboration.

As a result of the improvements and optimizations made to the SAB manufacturing process during commissioning of the line, Svante was able to produce a first complete set of 48 SABs for the 30TPD Pilot Plant that met quality specifications as of April, 2019. Examples of the first pilot-scale SAB production run are illustrated in Figure 10 below.

Figure 10: First set of 30TPD Pilot Plant scale structured adsorbent beds (S3, PEIDS) as at April, 2019

2.3.3 Execution, Construction and Installation

With the FEED stage of the engineering work for the 30TPD Pilot Plant significantly progressed by early 2018, the procurement of long-lead items and major equipment for the 30TPD Pilot Plant was enabled, with significant orders commencing in March, 2018. The detailed engineering work for the plant continued throughout 2018, with substantially completed Issued For Construction ("IFC") detailed engineering packages that comprised more than 8,000 3rd party engineering manhours and >700 drawings and documents available by the end of 2018. This facilitated the formal award of the fabrication, construction and installation contract for the 30TPD Pilot Plant on December 13, 2018. The 30TPD Pilot Plant represents the implementation of a true first-of-a-kind technology at significant scale, and the completion of the detailed engineering and IFC engineering packages did encounter challenges in cost and schedule which had an effect on final project timelines vs initial projections. In order to mitigate the impact of this, certain detailed engineering work, including structural, mechanical and piping for the top level of the plant module and final electrical, instrumentation and controls packages, continued throughout early 2019 in parallel to the fabrication, construction and installation of the plant at the Husky site.

Highlights of the execution, construction, and installation stage of the 30TPD Pilot Project are provided as follows, and Figure 11 illustrates these highlights corresponding to the project as-built timeline:

- Major equipment for the 30TPD pilot plant was ordered, procured, and delivered to the construction/fabrication site in Edmonton, Alberta or the installation site in Lashburn, Saskatchewan
- After more than 8,000 engineering manhours, the IFC (issued for construction) detailed engineering package for the 30TPD pilot plant was completed by December, 2018, with an initial partial IFC package provided by May, 2018
- The novel 400 Series RAM machine finished fabrication and underwent successful test assembly and factory acceptance at Arvos' Wellsville facility, and was subsequently shipped to the fabrication yard near Edmonton, AB, and underwent final installation in the 30TPD pilot plant skid on-site at Husky in Lashburn, Saskatchewan
- On March 18, 2019, the 30TPD pilot plant skid was successfully shipped from the modular fabrication yard near Edmonton, AB, to the installation site at Husky's facility near Lashburn, Saskatchewan – meeting this timeline was critical in order to avoid road bans for spring break-up in order to ensure no further delays to the project schedule
- On April 9, 2019, the final and 48th bed of the first complete set of 30TPD pilot plant adsorbent beds completed production and assembly

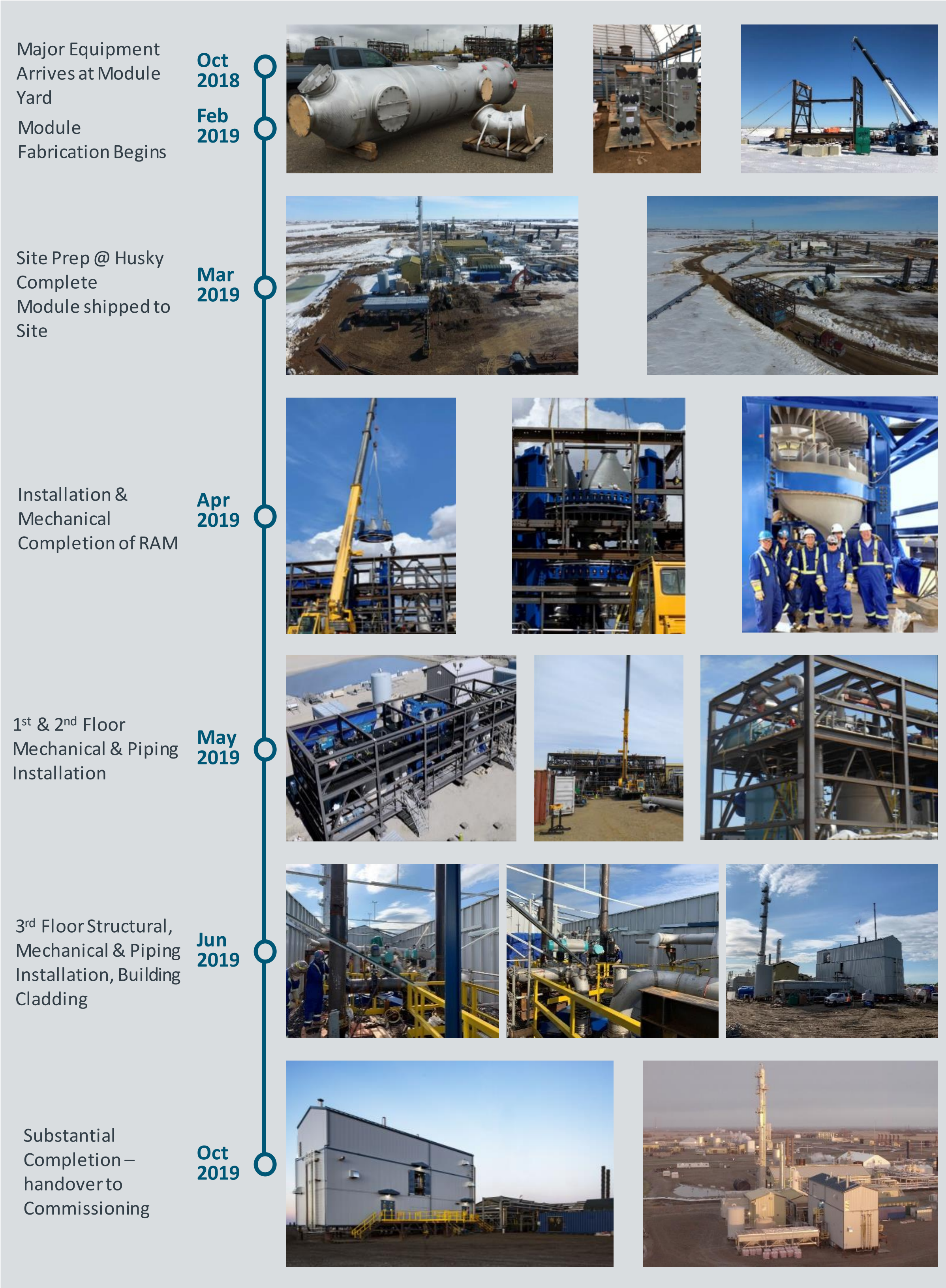

Figure 11: 30TPD Pilot Plant Construction Timeline Highlights

3. Lessons Learned

3.1 Technology & Product Roadmap

The primary learnings sought out during this ERA Project were with the respect to the development of a viable and competitive post-combustion CO_2 capture technology using the VeloxoTherm™ proprietary approach. The number of detailed technical learnings are confidential and too numerous to list here. It is possible, however, to identify some of the main technical breakthroughs, technology developments and product learnings achieved through the project, these are highlighted as follows:

- **Identification of high-performance fundamental adsorbent materials** – The switch to more advanced and tailored adsorbent materials was critical to the success of the 30TPD Pilot Plant. In addition, this pivot required Svante to develop world-class in-house expertise in active materials development which has become a critical competitive advantage of the Company.
- **Multi-disciplinary integrated development** – In completing a screening effort over a large number of potential adsorbent materials, Svante discovered that many efforts to develop CO_2 capture active materials are done as an isolated materials development R&D effort focused on a small number of physical parameters. By integrating a full set of expertise and staff across basic materials research, dynamic process cycle development, industrial process engineering and mechanical design, Svante was able to select adsorbent materials which would perform well in real industrial processes, as opposed to tightly controlled laboratory environments.
- **Importance of actual field testing** – Despite the use of best practices such as DFMEA/DVPR, HAZOP/LOPA, and sophisticated engineering design and simulation tools, there is no substitute for testing new technologies out in real world environments. The operation of the 0.5TPD Demo Plant was an important success factor in the project, allowing for critical learnings around SAB, process and plant design that helped to significantly de-risk and contribute to the success of the 30TPD Pilot Plant
- **Validity of RAM and SAB Product Approach** – One of the most important technical learnings from the 30TPD Pilot Plant was that Svante's product architecture for the core proprietary RAM, SAB, and process cycle design were successful, helping to de-risk further development of these products for larger commercial-scale markets.

3.2 Project Execution

With respect to the 30TPD Pilot Plant engineering, design, installation and construction, Svante did develop a set of best practices and learnings which can be categorized and summarized as follows:

Front End Loading & Pre-Project Planning

- Implement Front End Loading approach, along with Target Value Design and Integrated Project Delivery to ensure that constructability is considered early, estimates are high quality and scope is as complete as possible
- Apply rigorous, appropriate, and conservative contingency levels in all estimates, from scoping through budget control

EPC/EPC Engineering Design Oversight

- Build a rigorous quality management system for external engineering
- Adopt an Integrated Project Delivery model to ensure proper communication between all team members and stakeholders, employ senior, experienced engineering management to rigorously manage external EPC/EPCM firms

Project Controls & Execution

- Hire dedicated project controls personnel and implement high quality project controls and project management systems and processes regardless of project role – project success is critical and an owner's perspective is required

4. Market and Commercialization Plan

Svante's industrial CO2 capture technology is a disruptive 2nd generation approach that is expected to unlock and enable the market for widespread capture of industrial CO2 emissions. The global total addressable market for CO2 capture from industrial emissions using first generation technologies is measured at approx. $4 Trillion in initial capital equipment sales to remove 10 Gigatonnes of CO2 per year globally based on current technologies. Svante's technology would cut this figure in half to $2 Trillion, still representing one of the largest market opportunities for process technology ever, but at a much more competitive and affordable cost to end-users and project investors.

Svante is on the commercialization path. The Company has completed its development phase over the last 3 years, culminating in the commissioning of the 30TPD Pilot Plant. Over the next 3 years, the Company will industrialize and scale-up its product, supply chain and business in order to deploy an initial First-of-a-Kind (FOAK) commercial scale carbon capture plant of at least 1 million tonnes CO_2 per year with a series of lead customers and demonstrate market readiness for mass deployment. This 3 year "Industrialization Plan" will include commercial-scale manufacturing line for SAB beds, product development and prototyping of a larger commercial scale version of the RAM equipment, and business scale-up and commercial readiness initiatives required to properly execute on the Company's growth strategy.

Certain competitive and market access challenges and opportunities standout as primary drivers, and can be organized into major categories:

- Carbon pricing, incentives and emissions regulations – Jurisdictions such as the United States stand-out for their 45Q tax credit, which enables Svante's low capital cost technology to enable capture projects for industrial emissions where competitors cannot meet return thresholds due to high capital costs. Canada and the EU are also regions where carbon pricing is increasing and maturing, facilitating early market development
- Cost of CO2 capture – The overall cost of CO2 capture, along with the up-front capital cost, as compared with level of carbon pricing available constitutes the primary market driver for development of the CO2 marketplace – Svante's low capital costs enables its competitive advantage on this metric
- Net-Zero mandates and Voluntary Market for carbon pricing – As large corporate entities increasingly publish net-zero emissions mandates and become active in seeking emissions reductions and credits, a voluntary market is developing for CO2 reductions with pricing levels of >$100/tonne of CO2 possible. If this trend continues, capture projects which were previously uneconomic will become attractive, and the primary competitive advantage will become being the lowest cost CO2 capture technology