A Curious Journey to an Old Friend

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1. Introduction

For most of my 45 year career in the Energy Industry, my word-smiting skills have been an important part of my credentials. Thus after I retired (from Siemens in 2013), after I did some research on some important matters that related to my path forward (mostly climate change), and helped a former Siemens colleague start a new business (Microgrid Labs), I wrote my first paper for Energy Central in Sep 2017.

Ever since then, I've had two criteria for the subjects that I post to Energy Central:

1. They should be of interest to technical professionals in the U.S. Energy Industry.
2. They should be of interest to me, and within my skill set.

2. Backstories

I cast a wide net for the subjects on which I post papers. One of those is a weekly post by Forbes called "Current Climate." If you guess this is mostly about the impact of climate change on our current financial and business world, you are right. In the latest issue as I'm writing this (late February), I found a trail back to an old friend.

I mentioned in the beginning of the above Introduction that I spent quite a bit of time researching climate change. Eventually I decided that this was real, is the major challenge for the current and many future generations, and our society was (and mostly is) paying scant attention to it. Thus when I started writing my papers for posts, I decided that I would use much of writing to educate my readers about this issue.

When it comes to climate change, we are way past the time when simply ceasing the emission of greenhouse gas (GHG) is enough, although a really important first step. Thus came the realization that carbon capture and sequestration was a very important technology for both ceasing GHG emission, and the negative emission (of GHG) technology that we will need to use in the future.

As it happened, in 2020 I posted a paper on negative emissions technology (hereafter NET) where a then new technology was being used to supercharge an old method of carbon capture. This was described in section 3 of the post sumerized and linked below.

Tough Love – Part 2: *In this post we will look at possible roles of government, negative emissions technology, and a brief review of an excellent book on climate change politics.*

https://energycentral.com/c/ec/tough-love-%E2%80%93-part-2

The then new technology is described below in an excerpt from the above linked post.

The current state-of-the-art process for post-combustion carbon capture is liquid amine absorption. This has been used in many carbon capture projects, but it has two issues: (1) once the liquid amine absorbs the CO_2, substantial energy is required to release it, and (2) The amine solution degrades over time.

A recent discovery was made by the University of California (Berkeley) working with ExxonMobil in a project to improve the efficiency of amine CO_2 capture and release.

The team's recent discovery involves metal–organic frameworks (MOFs), a class of compounds consisting of metal ions or clusters linked by organic ligands to form one-, two-, or three-dimensional structures.

It has been known for some time that MOFs can host amine molecules, and work has been ongoing to improve stability of these and develop a low-energy CO_2 release mechanism. This work has led to a breakthrough in this project that is specifically applicable to Natural Gas Combined-Cycle Power Plants.

Today (late Feb 2023 as I'm writing this), I was reading the latest post of Forbes Current Climate, and came across a startup in Canada that is using MOF for carbon capture in fossil-fueled power plants, except they are well into the product production phase, and were noted in the Forbes post because:

… Svante, a Canada-based carbon capture startup, scored the biggest funding haul of the year, raising a $318 million Series E round led by Chevron Technology Ventures in December. Svante's technology involves metal-organic frameworks, which are porous compounds that it uses in filters to capture CO_2 from industrial flue stacks.

I normally don't cross over the border to cover Canadian Startups, but Svante is heavily funded by U.S venture capital, staffed by some U.S. personnel and is pursuing U.S. projects.

3. Technology

Solid sorbents, particularly metal-organic frameworks (MOFs), are a step change for the carbon capture industry. Their energy efficiency, resistance to degradation in the face of post-combustion flue gas impurities, and low cost of ownership make them ideal for carbon capture. That's why our team of scientists and engineers elected to use them in the first place.[1]

Our MOF captures CO_2 from diluted flue gas streams with high capacity and selectivity over water. It captures 95% of the total CO_2 emitted from industrial sources, adsorbing CO_2 using direct low-pressure steam injection for regeneration.

We've proven that MOFs are effective for industrial carbon capture. Our extensive research in this field has been published in Science Magazine, and we've been testing and optimizing our results in the lab and in the field for over 15 years.[2]

Most materials for carbon dioxide (CO_2) capture of fossil fuel combustion, such as amines, rely on strong chemisorption interactions that are highly selective but can incur a large energy penalty to release CO_2. Lin et al. show that a zinc-based metal organic framework material can physisorb[3] *CO_2 and incurs a lower regeneration penalty. Its binding site at the center of the pores precludes the formation of hydrogen-bonding networks between water molecules. This durable material can preferentially adsorb CO_2 at 40% relative humidity and maintains its performance under flue gas conditions of 150°C…*

[1] Svante Technology Page, https://svanteinc.com/carbon-capture-technology/

[2] Jian-Bin Lin et al, Science, "A scalable metal-organic framework as a durable physisorbent for carbon dioxide capture," 16 Dec 2021, https://www.science.org/doi/10.1126/science.abi7281 note that I needed to copy this link into my browser rather than just clicking on it. Full access is limited to members of AAAS.

Here we present Calgary Framework 20 (CALF-20), a MOF with high capacity and selectivity for CO_2 despite a physisorptive[3] mechanism and modest heat of adsorption. Its selectivity extends beyond N_2 to capture CO_2 in a wet gas. CALF-20 is exceptionally robust and stable to steam, wet acid gases, and even prolonged exposure to direct flue gas from natural gas combustion. Its single-step synthesis from commercially available components is highly scalable. The origin of the CO_2 attraction, despite CALF-20 being highly water resistant, was studied by simulation. Structuring of CALF-20 was performed, as well as competitive breakthrough experiments in wet gas streams that aligned with pure-component isotherms, heats of adsorption, and molecular modeling. In particular, not only can CALF-20 physisorb CO_2 up to and beyond 40% relative humidity, but the presence of CO_2 actually suppresses water sorption…

An ideal adsorbent for the post-combustion CO_2 capture should exhibit several properties, including (i) high CO_2 adsorption capacity; (ii) fast adsorption/desorption kinetics; (iii) high CO_2 selectivity over N_2, O_2, and ability to function in wet gas; (iv) mild regeneration conditions; (v) the ability to be formed into structures, e.g., beads, laminates, or monoliths; (vi) chemical, mechanical, and thermal stability during adsorption-desorption cycling; and (vii) low cost and scalability of production. We have shown that CALF-20 can meet all of these criteria and help make industrial-scale CO_2 capture cost effective and reliable. Other MOFs have better reported properties in one or more of the aforementioned criteria, but not in all of them…

4. How it Works

The following text is from reference 1.

4.1. CO_2 Capture Systems

Svante's technology is applicable to gas-fueled power plants and other CO_2-producing processes.

Our modular carbon capture machines are delivered to industrial sites, along with key balance of plant equipment — no complicated hazardous material, or space-taking chemical plants required.

These machines operate as described below:

Step 1: We place our filters inside our rotary adsorption machine or "RAM", which captures diluted CO_2 from industrial flue gas using our patented temperature swing adsorption process, VeloxoTherm™.

Step 2: As the filters rotate inside the machine, they adsorb diluted CO_2 from industrial flue gas and concentrate it into pipeline-grade CO_2.

Step 3: The compressed CO_2 product can be moved into a pipeline where it can safely be transported and stored deep underground in saline aquifers or recycled and used for to make other products.

[3] Physisorption, also called physical adsorption, is a process in which the electronic structure of the atom or molecule is barely perturbed upon adsorption. The weak, long-range bonding is not surface specific and takes place between all gas molecules on any surface. The process, which does not involve any surface reaction, is achieved quickly at low temperatures.

Svante has two different designs for their carbon capture machines: small (URSA 1000, captures approximately 500 tonnes of CO_2 per day) and large (URSA 2000, captures approximately 2,000 tonnes of CO_2 per day. The image below is the large version.

4.2. Svante's MOFs Reduce Risk

Reduced supply chain risk: *We've partnered with BASF, the world's largest chemical producer, to mitigate supply chain risk and scale-up the production of our MOF sorbent materials from lab to industrial scale. We've done this using a simple water-based process and green chemistry principles to minimize environmental impact.*

High CO_2 storage capacity means smaller inventory of adsorbent: *Our tailor-made solid sorbents have a high storage capacity for carbon dioxide. A sugar-cube sized quantity of our sorbent materials has the surface area of a football field.*

Fast CO_2 catch & release: *We've engineered our structured adsorbent beds (filters) to capture and release CO_2 in less than 60 seconds, compared to hours for other solid sorbent technologies.*

Proven & effective at separating CO_2 from nitrogen: *Our MOF sorbent material is proven and effective at separating CO_2 from nitrogen contained in diluted flue gas from power plants.*

Resistant to SOx, NOx & other impurities: *The MOF sorbent material we use has a unique resistance to SOx, NOx, oxygen impurities, and moisture swing. It's resistant to chemical degradation, which means less of a headache for operators and longer product lifetime.*

5. The Future for Svante

There are three things I look to determine future prospects of developing companies:

- How quickly a company has commercialized or is commercializing their technology.
- Their Senior Management and Board of Directors
- Funding.

5.1. Commercialization

Svante appears to be in a late pilot stage with their technology. I found two reports on this. The fist below is a recent feasibility report for a future project. The second is an article on a three-phase pilot project that is in-progress. There is a link to a third project at the end of this subsection.

5.1.1. Feasibility Report

The objective of Electricore's pre-FEED project "LH CO_2MENT COLORADO PROJECT" is to accelerate the implementation of a 1.5 million tonnes per year, and first-of-a-kind 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 Feasibility Study Report 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 per 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) 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 for intensified Thermal Swing Adsorption using Structured Adsorbent Beds and related Balance of Plant, including CO_2 compression.

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…[4]

Note the reference below contains a link to the Abstract, which in turn has a link to the full report. This is a "*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*" only, not a report on the full project.

[4] Jelen, Deborah, Electricore, Inc., submitted to U.S. Department of Energy, Office of Scientific and Technical Information, "LH CO2MENT Colorado Project Final Report," Dec 23, 2023, https://www.osti.gov/biblio/1907123

5.1.2. Pilot Project

Lafarge Canada, Svante and Total S.A. are celebrating the completion of Phase II of Project CO_2MENT, a first-of-its-kind partnership to capture industrial levels of CO_2 emissions from a cement plant.[5]

The completed phase consisted of construction and installation of the Svante capture unit at Lafarge Canada's Richmond, B.C., Cement Plant. The plant is now able to capture the CO_2 contained in its flue gas and to reuse it for CO_2-cured concrete, thus storing it permanently. Coupling this equipment with the alternative fuels used at the Richmond facility creates the world's first full-cycle solution to capture and reuse CO_2 from a cement plant, noted Lafarge Canada. The carbon-efficient examples achieved at the plant are leading the way to a near-zero emissions cement facility…

Phase III of Project CO2MENT, scheduled for construction over the next three years, will include the installation of a liquefaction unit and the development of an expansion project to further reduce emissions, as well as a business case review for further expansion across the Lafarge network.

Note that the above article is from Feb 2021, so Phase III has not been completed yet.

5.1.3. Chevron's Kern River oil field

Note that Chevron has been a major investor and partner of Svante since they were founded (see the last section below). They have a joint DOE-funded project in the subsection title facility near Bakersfield, California. I looked for a good text describing this. The bad news is that I never found it. The good news is that I found an excellent presentation, which is linked below.

https://netl.doe.gov/sites/default/files/netl-file/22CM_PSC16_McLemore.pdf

5.2. Senior Management & Board

The site linked below has both a thorough description of the Senior Management and Board. The board is mostly filled by major investors, with one notable exception: *Dr. Steven Chu, Nobel Laureate and Former US Secretary of Energy. Steven Chu is currently the William R. Kenan, Jr. Professor of Physics and Professor of Molecular and Cellular Physiology at Stanford University. He served as Secretary of Energy in the first Obama administration.*

https://svanteinc.com/about-us/

The page linked above also has a history of Svante.

5.3. Funding

Svante has gone through the following rounds of venture capital funding:

- Series A&B: Roda Group, Mitsui, Chevron and Chrysalix, 2017 (amount not found)
- Series C: OGCI Climate Investment, Roda Group, Husky Energy, Chevron Technology Ventures, Business Development Bank of Canada $13 million, 2019

[5] Cement Products, "Project CO2MENT Hits Major Milestone," Feb 15 2021, https://cementproducts.com/2021/02/15/project-co2ment-hits-major-milestone/

- Series D: Temasek Canada (EDC), OGCI Climate Investments, BDC Cleantech Practice, Chevron Technology Ventures, The Roda Group, Chrysalix Venture Capital, $75 million, 2021
- Series E: led by Chevron New Energies, with participation from Temasek, OGCI Climate Investments, Delek US, Hesta AG, 3M Ventures, Full Circle Capital, GE Vernova, Japan Energy Fund, Liberty Media, M&G Catalyst, Samsung Engineering, TechEnergy Ventures and United Airlines Ventures. $318 million, 2022

Note that Chevron participated in all rounds, and was the lead investor in Series E. I found the following joint news release by Chevron and Svante regarding this investment:

HOUSTON/VANCOUVER, Dec. 15, 2022 – Chevron New Energies (CNE), a division of Chevron U.S.A. Inc., and Svante announced that Chevron is the lead investor in Svante's Series E fundraising round, which raised $318 million that will be used to accelerate the manufacturing of Svante's carbon capture technology.[6]

"We are advancing a full value chain carbon capture, utilization, and storage (CCUS) business and believe Svante is poised to be a leader in enabling carbon capture solutions," said Chris Powers, vice president of CCUS with CNE. "Innovation is key to enabling these types of breakthrough technologies and lower carbon solutions, and we look forward to applying our experience and expertise to help drive this effort forward."

Since its founding in 2007, Svante has developed carbon capture and removal technology using structured adsorbent beds, known as filters. This funding will support Svante's commercial-scale filter manufacturing facility in Vancouver, which is anticipated to produce enough filter modules to capture millions of tonnes of carbon dioxide (CO_2) per year across hundreds of large-scale carbon capture and storage facilities.

"We are proud that Chevron and a group of existing and new strategic and financial investors have demonstrated their confidence in Svante to be a key player in building a commercially viable carbon management industry," said Claude Letourneau, President and CEO of Svante. "We are working to remove the biggest barriers to rapid deployment of industrial carbon capture by building this manufacturing facility, which we expect will enable us to rapidly expand our order book."

The size and cost of installing carbon capture technology has been a barrier to industry adoption. Svante's modular solid sorbent technology is designed to capture CO_2 from industrial flue gas. It then concentrates it into a high-purity, 95-percent pipeline-grade CO_2 to prepare it for storage or further industrial use. Its approach is tailored specifically to the challenges of separating CO_2 from nitrogen in diluted flue gas, which is typically emitted at low pressures, and in dilute concentrations. Svante's technology is targeted toward industrial decarbonization activities in fields including hydrogen, pulp and paper, lime, cement, steel, aluminum, and chemicals. Svante's filters are also available for direct air capture and carbon dioxide removal.

[6] Creighton Welch, Chevron, Colleen Nitta, Svante, "chevron invests in carbon capture and removal technology company, svante," Dec 15, 2022, https://www.chevron.com/newsroom/2022/q4/chevron-invests-in-carbon-capture-and-removal-technology-company-svante

In 2021, Chevron launched CNE to accelerate lower carbon business opportunities in CCUS, hydrogen, renewable fuels and products, offsets, and emerging technologies. Chevron plans to invest $10 billion in lower carbon projects through 2028 and remains committed to collaborating in new ways to accelerate progress.

Chevron Technology Ventures made an initial investment in Svante in 2014. In 2020, Chevron launched a project to pilot Svante technology to capture CO_2 from post combustion of natural gas. The project has received funding from the U.S. Department of Energy (project #DE-FE0031944). In collaboration with Svante and the National Energy Technology Laboratory, the technology will be tested at Chevron's Kern River facility in San Joaquin Valley, California, with startup underway this month…

Final author's comment: Some readers might consider Chevron's heavy involvement with Svante a bad thing. I think the opposite. As we (the residents of the world) reduce our demand for petroleum products over the next few decades, companies like Chevron need to find new business opportunities. To do less would be a violation of due-diligence demanded by their investors. The best path forward would be for Chevron et al to become part of the climate change solutions. I have stated this opinion in prior posts, and I will continue to express it.