Delicious Carbon Capture

By John Benson

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1. Introduction

I subscribe to many information sources, but occasionally, a lead for a really good paper comes from our local paper in the Livermore Valley, "The Independent." This paper covers the usual breaking news, sports and community events, but also covers major government facilities in the valley, like Lawrence Livermore National Lab (LLNL) projects and the Livermore Campus of Sandia National Lab. Even though long-time local residents (like your author) jokingly call LLNL "The Bomb Factory," many of the Lab's projects do not involve nuclear weapons, like the subject of this article.

One other back story: Your author, enjoys a few glasses of wine and occasionally beer, generally after 5:00PM. I tend to favor the beverage made from grapes, because, (1) in my earlier years I was an amateur wine-maker, and (2) the Livermore Valley is a major Winery Region, with over 40 wineries.[1]

You ask: "What the heck does wine have to do with carbon capture or National Labs? Ah-ha, Gotcha!

2. The Perfect Carbon Capture Process

Wineries may soon play a significant part in carbon sequestration, thanks to the work of local scientists.[2]

A team at Lawrence Livermore National Laboratory (LLNL) recently completed, a proof-of-concept demonstration for the idea at the Continuum Estate Winery in St. Helena. The project captured off-gasses from fermenting wine grapes and then mineralized the carbon dioxide, keeping the carbon out of the atmosphere.

Fermenting wine grapes in California alone produce some 450,000 tons of carbon dioxide per year, according to LLNL, equivalent to the annual emissions of almost 100,000 cars.

To achieve our mid-century climate goals and avert the more disastrous effects of climate change, the world must remove carbon from the air in addition to reducing emissions, according to an LLNL carbon-removal report released last year. Toward that end, the U.S. must remove carbon on the scale of a billion metric tons per year by 2050.

One promising avenue for carbon removal involves rethinking how industries handle biomass - the organic material created through agriculture. "Plants have done the work of taking the sun's energy and putting that into chemical energy, into the sugar," said LLNL Staff Scientist Nathan Ellebracht.[3] *"Fruit is really packed with sugar. That is where the CO_2 from the atmosphere is going; into the sugar that is in the fruit."*

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[1] Livermore Valley Wine Community / Livermore Valley Winegrowers Association, https://www.lvwine.org

[2] David Jen, The Independent, "LLNL Explores Carbon Capture with Wineries," March 28, 2024 Issue. The following link is to a summary of this article.: I scanned in the full article, and then edited for content. https://www.independentnews.com/news/livermore_news/llnl-explores-carbon-capture-with-wineries/article_34152a08-ec93-11ee-bf03-6f176695bdff.html

[3] https://people.llnl.gov/ellebracht1

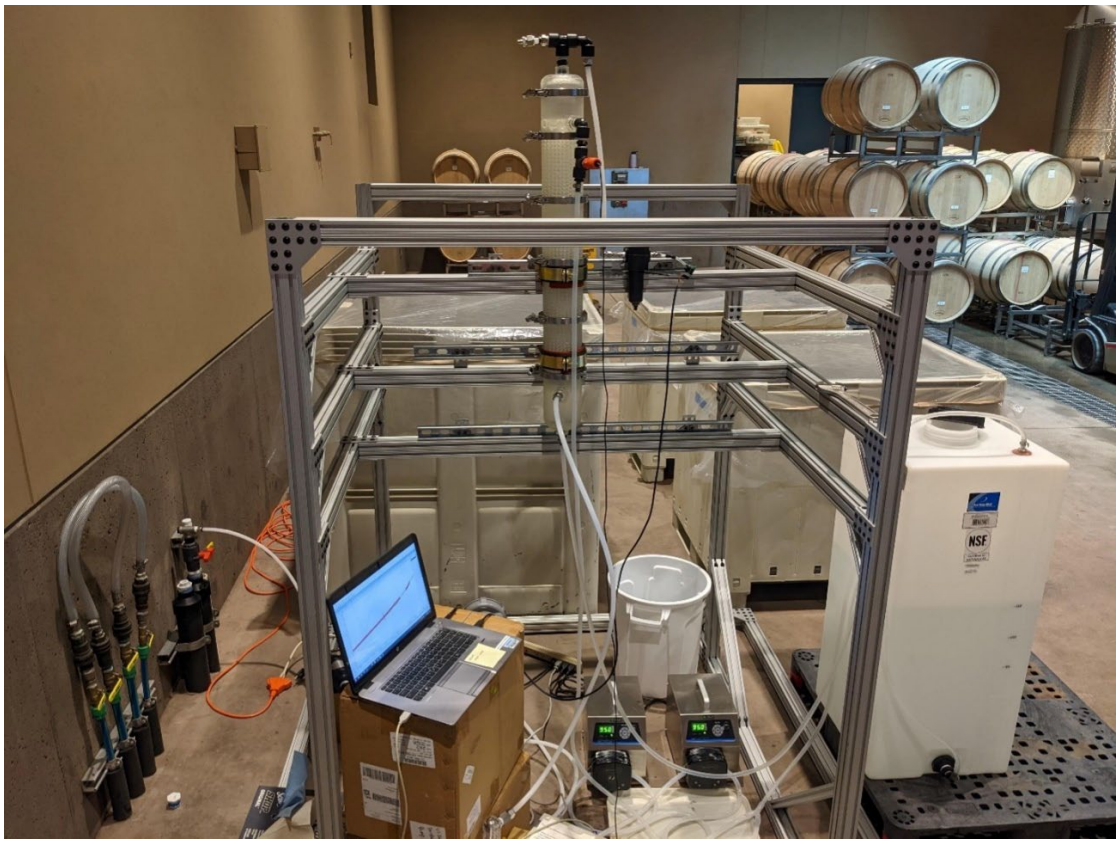
Ellebracht and his team installed a carbon capture system at Continuum to collect the off gass.es of fermenting grapes and mineralize them into a form suitable for long-term storage.

The project piped fermentation gasses through an absorber tower that allowed the carbon dioxide from the grapes to react with a solvent. The reaction produced a mineral called nesquehonite that holds the carbon.

Compared to the emissions of a power -plant, composed of about 4% carbon dioxide, the gasses from the fermenters are almost pure carbon dioxide, allowing for carbon capture with very low power requirements, said Ellebracht. Such efficiency is important, as energy-intensive processes may end up producing more carbon than they remove because of the emissions involved with electricity generation.

Ellebracht also saw Continuum as a special-case. "They actually have centralized plumbing for all of their fermentation off gas, where they have a cap on all their fermenters and they pipe the CO_2 that's coming off into a single, centralized system."

Other, older wineries simply let the gasses float away during fermentation, and installation of such centralized plumbing would be expensive, he continued.



CO_2 off-gas from tanks of fermenting wine at Continuum, a Napa Valley winery, travels through plastic tubing and into the bottom of Livermore's absorber tower. Liquid solvent from the square container (right foreground) flows through the absorber packing.

3. If You Prefer Brewskis

Sometimes a scientific breakthrough can end up in the most unexpected places. Just ask Congwang Ye, a Lawrence Livermore National Laboratory (LLNL) engineer[4] whose work with carbon capture microcapsule technology, intended for filtering CO_2 from power plants, could end up solving a big problem for craft beer makers.[5]

In December, 2016 Ye participated in the Department of Energy's Lab-Corps Pilot Program, an intensive eight-week entrepreneurial boot camp that teaches scientists and engineers the tricks of the trade for spinning out technology from LLNL to the marketplace. Part of the Lab-Corps curriculum requires participants to conduct 100 interviews with prospective customers to discover how to adapt technology to business.

With such a small window of time, Ye, the team's principal investigator, needed something that could be marketed easily. The first idea was to replace the existing CO_2 filters used in anesthesia machines, which got the team started. One interviewee even offered to place an order right away. However, Ye's industrial mentor, Gerry Barañano, a veteran entrepreneur from Tech Futures Group, pointed out the limit of market size, so they quickly pivoted.

"We avoided spending weeks of time on something less meaningful because of his entrepreneurial instinct," Ye said.

After considering several applications that might benefit from reusable microcapsules that can rapidly absorb CO_2, including waste gasification, fertilizer production and deep-water diving, he didn't have to go far to find the next promising lead. Lab-Corps happened to be held in Golden, Colorado, the home of Coors Brewing Company and part of the Denver metro area, which boasts more than 200 microbreweries.

The team's entrepreneurial lead, Lionel Keene, an LLNL engineer who once founded his own software company, suggested contacting Coors, and the group talked their way into touring the facility, which they found had an aging CO_2 reclamation system.

"Luck plays a big role in a lot of these things and frankly, we got lucky," Keene said. "We had a flexible product, so if one thing didn't work out, we could find somewhere else where it might be useful. Sometimes it's just a matter of talking to the right person."

In meeting with Coors and a local CO_2 supplier, Ye and Keene learned that during the fermentation process, breweries produce about three times the amount of CO_2 needed for carbonization and packaging. Coors, for example, generates roughly 300 million pounds of carbon dioxide per year during the fermentation steps, but only needs 80 million pounds, most of which is currently purchased through suppliers. Furthermore, typically 80 percent of the cost of purchasing CO_2 comes in transportation. If breweries could capture and reuse CO_2 using the microcapsules, Ye thought, they could be self-sustaining and sell the excess to other nearby consumers.

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[4] https://people.llnl.gov/ye4

[5] Jeremy Thomas, LLNL Article, "Lab-Corps experience inspires application of carbon capture technology to untapped industry,"Feb 15, 2017, https://www.llnl.gov/article/43091/lab-corps-experience-inspires-application-carbon-capture-technology-untapped-industry

"We want to adapt this technology for capturing CO_2 in breweries as a way to reduce CO_2 emissions to the atmosphere and cut their purchase costs by up to 75 percent," Ye said. "It will be more environmentally friendly, and not only will it save on costs, but they also can create revenue by selling the excess."

Author's comment: A Pilsner-Style Beer is naturally carbonated: *Natural carbonation involves capturing the CO_2 in the beer during the fermentation process, rather than allowing it to escape into the atmosphere and then adding it back via forced carbonation. During this process, the carbonic acid binds to the flavor and aroma compounds in the beer.* [6]

But before working their way up to the big guys, Ye and Keene realized they would have to start out with small producers. They focused their attention on microbreweries, which generally can't afford large commercial CO_2 reclamation systems but produce enough carbon dioxide to make an impact. During the visits, they were amazed by pioneering ecosystems that also could benefit from a more efficient carbon capture technology. While in Colorado, they visited Upslope, a craft brewery that works with Boom Algae, an algae company, to capture CO_2 for algae growth, that eventually converts into a green ink they use in menus and promotional literature.

The breweries were interested, but they didn't like the idea of a large, monolithic system. Ye's group presented a "propane tank model," a basic CO_2 capturing system using barrels filled with millions of microcapsules that could absorb CO_2 from the fermentation gas. In theory, Ye's company -- with a working name of MECS (Micro-Encapsulated CO_2 Sorbent) -- would provide the equipment at no cost upfront, the brewers would collect CO_2 gas from the fermenters, fill the tanks and MECS would send trucks to pick them up. The captured CO_2 would be reclaimed at a centralized hub, sold back to brewers at a big discount, and MECS would keep the surplus and sell it on the open commodities market. The idea could potentially save breweries tens of thousands of dollars a year, Keene said.

While applying for the DOE's Technology Commercialization Fund, Ye is shopping the smaller-scale carbon capture technology around to craft breweries. He's also in discussions with UC Davis, which has a pilot-scale winery and brewery, to install the system to prove the concept works. Ye also believes existing CO_2 suppliers could be partners, instead of competitors.

"Their trucks need to come out to deliver CO_2 anyway, and could easily swap our capture tanks in the same trip," Ye said. "Working with us means they would have an option to possess commodity, be less dependent on the major CO_2 distributors and to expand their own business."

If it hadn't been for Lab-Corps, Ye said he never would've thought about applying his technology to the beer industry. The experience, he said, taught him to think about how science can be practically applied to the marketplace, the importance of communicating with potential customers and how to work with seasoned mentors to come up with a plausible business plan.

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[6] Winslow Sawyer, Pure Brewing, "Natural Carbonation In Your Beer," Dec 2020, https://www.purebrewing.org/education/beer-101/natural-carbonation/

"The point of Lab-Corps is to take lab technology and think outside the box," Ye said. "When we get to talk to the real consumers, they tell us something else they care about, and it opens your mind to things you wouldn't have thought of in the lab. You find out their actual needs, and it makes your proposal more powerful. Lab-Corps has helped personally to develop the skills to talk to strangers and find information from the conversations. The experience helped me think about the technology and how to adapt it for what people actually want..."