Two New Processes for Carbon Removal and a Monitor

By John Benson

August 2024

1. Introduction

Virtually all experts on climate change mitigation agree that, in order to do this rapidly enough to avoid really major repercussions (like many coastal areas under water, mainly from melting Greenland and Antarctic Ice Sheets), we need to actively remove greenhouse gasses from the atmosphere. The main key for developing a viable technology it to reduce the net cost of doing this below $100 per ton of CO_2 removed. Within viable pathways to this goal there are at least two approaches. One relies on a boost from Mother Nature, and the other subsidizes the CO_2-removal with a salable side-product. Those two approaches are examined in this post.

2. Graphyte's Biomass Boost

Your author receives several newsletters from Forbes. One of them is weekly newsletter on climate change: Current Climate. The 7/22 issue had an article on the title technology, which was an interview with Barclay Rogers, founder and CEO of Graphyte. This interview follows. Note that the reference below is from a Graphyte reprint of part of this interview.

Question: There are a number of different technologies for carbon removal. What's the advantage of biomass-based solutions?[1]

Answer: I went and pulled the data. What you see is that biomass-based solutions are the dominant players with respect to volume. This is interesting to me because this isn't the story that people are talking about. They are talking about direct air capture. But biomass-based approaches are getting to market faster. I call this the dark horse story. If you think about it as a horse race, we thought we had a clear winner, and, oh look, there's a horse that no one thought was going to run that is running really hard.

Question: Why is biomass gaining?

Answer: The hardest part is separating the CO_2 from atmospheric air. That takes a lot of thermodynamic work. The biomass-based approaches let you do that for free. What that means is it's a lot cheaper.

Question: What is Graphyte doing?

Answer: Our project in Pine Bluff, Arkansas is one of the biggest or the biggest. It has the capacity of 15,000 tons of CO_2 removed per year. We intend to commence construction in early 2025 to add 50,000 tons of removal capacity to take it collectively to 65,000 tons by the end of 2025. We went from company formation in February 2023 with an initial investment from Breakthrough Energy Ventures, the Bill Gates climate-focused investment fund, to an operating facility with capacity of 15,000 tons a year 14 months after the company formation.

[1] Amy Feldman, Forbes, "Graphyte Q&A: Forbes' Current Climate Newsletter," July 22, 2024, https://www.graphyte.com/post/graphyte-q-a-forbes-current-climate-newsletter

Question: What does it cost?

Answer: Our sales price is $100 a ton. This is what everybody aspires to get to someday. We are there today.

Question: How does it work?

Answer: This is what we call carbon casting. The issue is that the carbon captured by biomass is released back into the atmosphere primarily because it is left to decompose. A tree falls into the forest, rots and the carbon contained within it is released back into the atmosphere. We take the residuals from the agriculture and timber industry and that becomes the feedstock. Think about growing rice. The hulls or husks around the grain and the straw left in the field are generally left to decompose. We can take those products and use them as feedstock.

We take the biomass material. We grind it up to smaller particle size. We then drive it down to a certain moisture content, press it into blocks and encase those blocks in a long-lasting waterproof barrier. It's all about keeping it dry. We essentially seal the biomass in that bag that's intended to keep it dry for 1,000 years or more. It's below the ground, and we put soil back on top of it.

Question: Is it hard to get communities to agree that they want this biomass burial site underground?

Answer: The process is super land efficient. We store 40,000 tons of CO_2 equivalent per acre of land. Our sequestration in Grant County, Arkansas is about 40 acres of operating area. Forty acres is not very big in a rural setting.

Question: Who are your customers?

Answer: We have one customer that is public, and quite a few customers that have yet to be public though that will change in the second half. Our publicly disclosed customer is American Airlines. They're interested in durable carbon removal, but all the solutions have been out of reach. They saw us at $100 a ton, and said they can do that.

Question: How many customers total?

Answer: More than 10.

Question: So, what does that mean in terms of your capacity for carbon removal?

Answer: We plan to increase our removal capacity from 15,000 tons a year to 5 million tons by 2030.

Question: Is that realistic?

Answer: Very much so. We have plenty of biomass, we have a workable technology today and projects literally in development. The only things we need are customers willing to pay for it.

Question: We would have to build a number of plants. Each one we start at 50,000 tons per year with the capacity of scaling to 500,000 tons. So, if you go back to that 5-million-ton number, we'd need 10 projects. Among the advantages of carbon casting is that it is relatively capital efficient. We don't need to raise $1 billion to build a plant. We can build a plant for a little over $10 million.

Author's comment: The above interview had a link to another article. Most of the information in the second article was redundant with the above, but there was one piece of additional information. In order to shorten this information, I am only providing the answers, which appear to be capable of standing alone.

"First thing to understand is, in the low-carbon economy, we're a new startup company focused on broad efforts to decarbonize the broad economy," Rogers, 49, said. "I think the broader answer is -- let's look at Fortune 500 companies -- two-thirds of Fortune 500 companies have made carbon-neutral pledges or some version of a carbon pledge, and we are in the business of helping those companies fulfill those pledges. It is a commercial activity and not a government initiative in any form."[2]

Three partners for Graphyte's services have been secured -- two of whom Rogers was authorized to mention. One is Arkansas River Rice in Pine Bluff, which is said to be the only Black-owned rice mill in the U.S., and the other is Anthony Timberlands in Malvern, Arkansas.

"They're really making a dent in carbon removal, because they're taking a byproduct we really don't use anyway and turning that into permanent carbon removal," P.J. Haynie, co-owner of Arkansas River Rice, said of Graphyte. "That's the cool part. The rice that we're growing, we're trying to put it in an environmentally friendly way and a climate-smart way. We're reducing our methane gas emissions, and when we're working with Graphyte, what we're doing is to take that carbon out. People don't really understand the big picture of what we're doing in Pine Bluff, and it's huge."

3. Babcock & Wilcox's BrightLoop™ Technology

The BrightLoop system produces clean energy with complete in-situ CO_2 capture. You can simultaneously accomplish low-carbon initiatives and energy transition objectives. Just as importantly, there is built-in flexibility to maximize its potential for your specific needs.[3]

3.1. Solution for Low-Carbon Energy

As the world advocates for decarbonization, industry is responding by looking for innovative ways to optimize its processes for a cleaner tomorrow. Emerging technologies to support the continuous drive to reduce greenhouse gas (GHG) emissions can form a cornerstone of corporate stewardship.

The BrightLoop™ process from Babcock & Wilcox (B&W) is a versatile and flexible technology which can be used for a wide range of applications. We've demonstrated that BrightLoop can effectively separate carbon dioxide (CO_2) while producing hydrogen, steam and/or syngas, as well as being ready for commercial scale-up.

[2] I.C. Murrell, Arkansas Democrat Gazette, "New emission-reducing firm coming to Pine Bluff," Nov 14, 2023, https://www.arkansasonline.com/news/2023/nov/14/new-emission-reducing-firm-coming-to-pb/?utm_source=newsletter&utm_medium=email&utm_campaign=currentclimate&cdlcid=628673ca6e1a1d1211f1d747&section=reading

[3] Babcock & Wilcox, BrightLoop™ Technology Brochure, https://www.babcock.com/assets/Uploads/E101-3260-BrightLoop-for-H2-Steam-or-Syngas-Production.pdf

A particle breakthrough made it happen. Our proprietary particle is an extremely versatile oxide in terms of application, cost and abundance making chemical looping possible for practical implementation in a low-carbon world.

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- *HYDROGEN FROM MULTIPLE FEEDSTOCKS B&W's BrightLoop chemical looping technology utilizes a variety of solid and gaseous fuels as feedstock to produce a stream of nearly pure hydrogen separate from a stream of CO_2. This greatly reduces the amount of energy and fossil fuel required to produce hydrogen from hydrocarbons while also effectively and inexpensively isolating carbon dioxide.*
- *COMPETITIVE HYDROGEN COST BrightLoop chemical looping can produce low-carbon hydrogen at a cost better than current large-scale hydrogen generation technologies such as steam methane reforming (SMR) with carbon capture or electrolysis.*
- *HIGH RATE OF CARBON CAPTURED Inherent CO_2 isolation without the need for expensive carbon separation equipment is part of the process. Generally, BrightLoop also has much lower Carbon Intensity (CI) scores as compared to other hydrogen production methods when combined with carbon capture due to the inherent separation of CO_2 and the wide range of feedstocks available. It has the potential to allow the continued use of solid and gaseous hydrocarbons in a cleaner, more environmentally friendly way, while still contributing to net-zero goals.*
- *SCALABLE FOR A RANGE OF APPLICATIONS The BrightLoop process is scalable to accommodate small, medium and large applications. These various sizes accommodate market needs such as supporting local generation for transportation, centralized hydrogen hub generation, and industrial uses.*

3.2. The BrightLoop Process

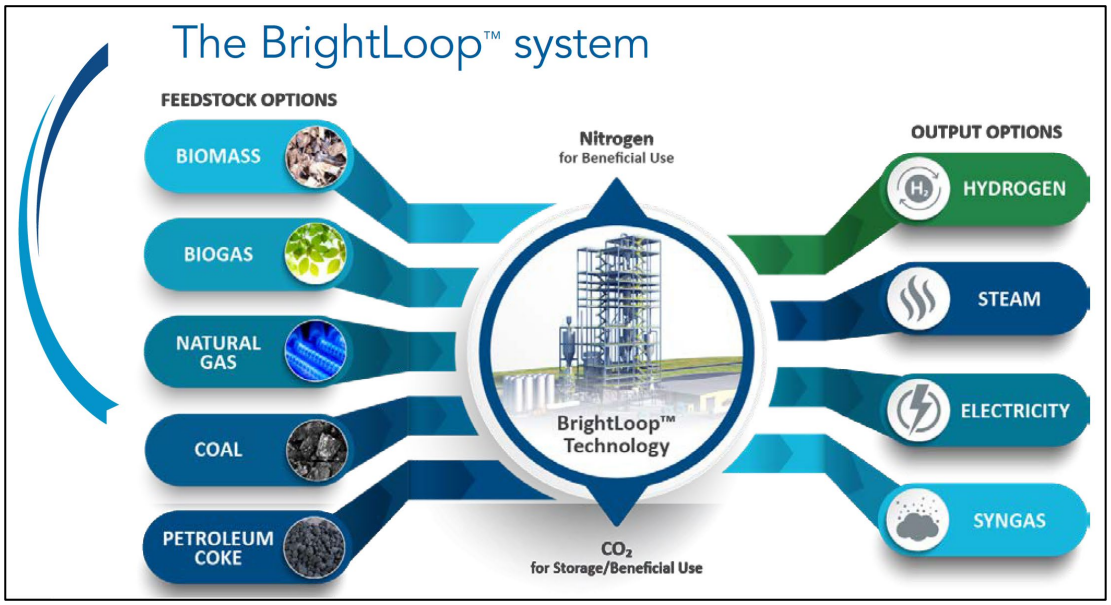
The BrightLoop technology is a novel chemical looping process that is based on the oxidation and reduction of an oxygen carrier particle. The feedstock reacts with oxygen-carrier particles in a fuel reactor, forming reaction products which are predominantly CO_2, while reducing the oxygen-carrier particles.

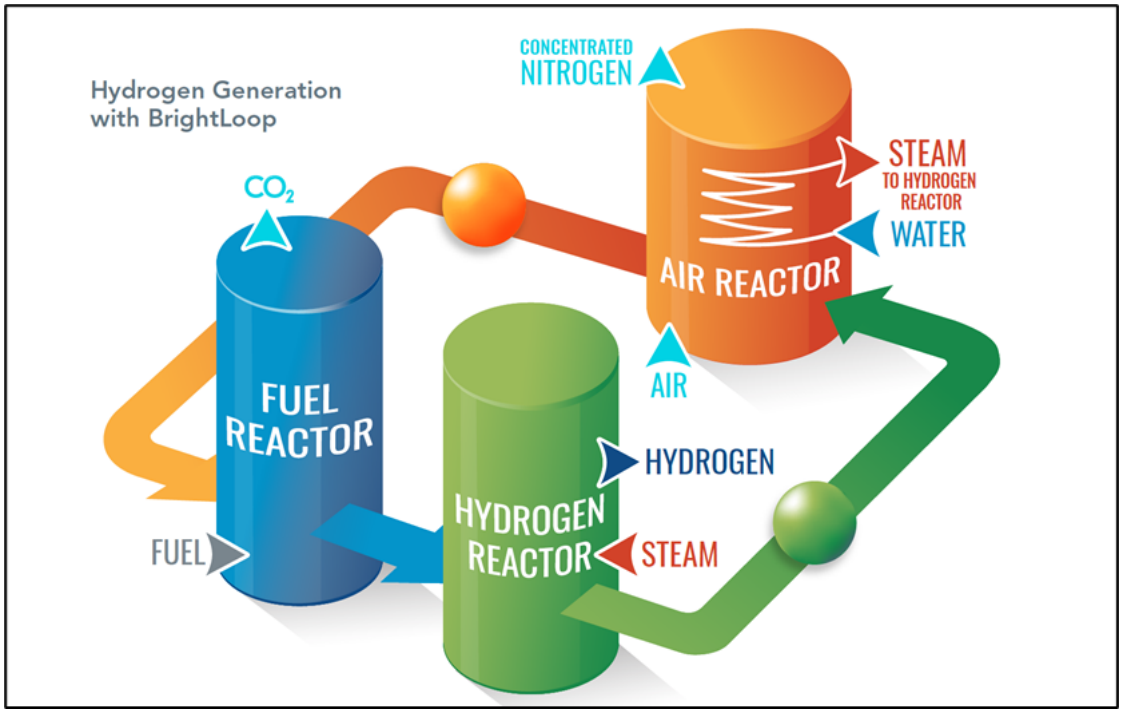
The reduced oxygen-carrier particles then move to a hydrogen reactor where they react with steam to partially oxidize the particles and generate a stream of hydrogen. This reaction means that the hydrogen is produced from the steam – it is not separated from the other constituents of the feedstock.

The oxygen-carrier particles are then transported to an air reactor where they are regenerated with air back to their original state. The products of these reactors are predominantly concentrated nitrogen with minimal oxygen. The fully regenerated particles are then returned to the fuel reactor to continue the "loop" process. The fuel and hydrogen reactors use moving-bed technology while the air reactor uses fluidized-bed technology.

Gaseous products generated in each reactor are cooled using various heat exchangers including steam generators that produce the steam needed to create hydrogen and cleaned of undesirable emissions using typical environmental control technologies.

The process can also be configured to produce steam for process or electricity generation, or syngas for liquid fuel or methanol production, all with CO_2 isolation.





3.3. Wide Range of Applications

- *Small Scale: 1–3 tons per day of hydrogen for industry, industrial equipment or transportation*
- *Medium Scale: 10–50 tons per day of hydrogen for industry*
- *Large Scale: 100–250 tons per day of hydrogen for central hub and power generation*

3.4. Ready for Commercial Deployment

Under a DOE-sponsored project, B&W built a 250 kWt (kilowatts of thermal energy) coal-based CDCL pilot facility to demonstrate the fuel reactor and air reactor operation for application to steam (and subsequently, power) generation. On another project, continuous low-carbon hydrogen generation was demonstrated at the 250 kWt pilot unit constructed and tested at the National Carbon Capture Center in Alabama.

Given the success of the pilot units, we are ready to commercially demonstrate the technology at a larger scale. B&W is working on projects to demonstrate low-carbon hydrogen and steam production while utilizing the most applicable fuel feedstock.

4. Better Greenhouse Gas Monitoring

Currently high-altitude greenhouse gas is mainly monitored from above (Satellites) or below. This is not optimal. However, an innovative collaboration may remedy this.

NOAA and United Airlines have announced an agreement to equip a Boeing 737 with a sophisticated instrument package that will measure greenhouse gases and other pollutants during domestic flights. It's a first step in establishing a partnership that could significantly improve monitoring of carbon dioxide, methane and other greenhouse gases, as well as improving the accuracy of weather forecasts in the United States.[4]

The multiyear agreement is designed as a test for a potential larger network of instrumented commercial aircraft that would allow for continual monitoring of greenhouse gases and key observations, like water vapor, above large metropolitan regions in the U.S. and neighboring countries. The agreement, a Cooperative Research and Development Agreement (CRADA), was announced today at the White House Super Pollutants Summit held in Washington D.C.

"This collaboration represents a significant leap forward in U.S. efforts to monitor and mitigate greenhouse gas emissions," said Sarah Kapnick, Ph.D., NOAA's chief scientist. "If we can harness the capabilities of commercial aircraft we will be poised to make rapid advancements in the understanding of greenhouse gas emissions that can inform policies."

[4] Theo Stein, National Oceanic and Atmospheric Administration (NOAA), "NOAA and United Airlines partner to measure greenhouse gases, pollutants with high-tech flight instruments," July 23, 2024, https://www.noaa.gov/news-release/noaa-and-united-airlines-partner-to-measure-greenhouse-gases-pollutants

4.1. The benefits of in-flight sampling of the atmosphere

NOAA's Global Monitoring Laboratory (GML) operates a network of 60 sampling sites around the world, and contracts with private pilots to collect airborne samples during 14 regular flight routes in the U.S. an average of three times a month. Analysis of these samples provides data that allows scientists to accurately track the global increase in carbon dioxide and other greenhouse gases, which they incorporate into NOAA's Global Greenhouse Gas Reference Network[5], one of the foundational research tools used by climate scientists.

New and existing satellites have increased scientists' ability to monitor many greenhouse gas super pollutants, such as methane, but satellites do not measure them directly. Direct measurements of atmospheric composition by airborne instruments remain the most effective way to validate satellite observations.

NOAA, along with partners like NASA and the National Science Foundation, regularly conduct atmospheric research missions to make direct measurements, but these campaigns are costly and limited in terms of how much area they can cover and how long the instruments remain in the air. Installing instruments on airliners would vastly increase the number and distribution of samples that would be collected.

"We'll be collecting data over multiple cities multiple times a day, in different seasons, and under varying weather conditions," said Colm Sweeney, who leads GML's commercial aircraft program. "This will allow scientists to more accurately measure U.S. emissions at sub-regional scales, which is one goal of a national greenhouse gas monitoring strategy announced earlier this year, and at just 1% of the cost of deploying research aircraft," Sweeney said.

Combining vertical greenhouse gas and weather profiles from instruments on commercial aircraft with satellite observations would create a continuous monitoring system in the United States. By certifying this instrument set for the Boeing 737, flown by airlines throughout the world, other countries will be able to quickly adopt this technology for their own climate monitoring…

While using commercial airplanes to collect important scientific data would be a new strategy for GML, NOAA'S National Weather Service has been doing it for years. Every day, commercial airliners collect critical weather observations that not only improve aviation safety and the operations of the U.S. National Airspace System, they dramatically improve the weather forecasts relied on by all Americans…

[5] https://gml.noaa.gov/ccgg/about.html