Utah-Based Startup Eyes Forest Waste to Fuel Future Flight: Q&A

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A Utah-based startup backed by the US Department of Defense is seeking to turn forestry waste and agricultural biomass into a high-quality, energy dense 100% sustainable aviation fuel to help the industry achieve its decarbonization goals.

"If you want to make a meaningful impact on a hard-to-decarbonize sector like aviation — and long-haul transport — then it means energy dense, hydrocarbon light liquids that are produced using renewable feedstock," Mukund Karanjikar, chief executive officer of CleanJoule Inc., told BloombergNEF in an interview. "That is the only real, credible near-term option to decarbonize aviation."

CleanJoule this week announced that its product, dubbed CycloSAF, had formally entered a certification program — the American Society for Testing and Materials International's D4054 process — for qualification to be blended with conventional jet fuel. By relying on forestry waste as a feedstock, CleanJoule says its sustainable aviation fuel, or SAF, will help reduce price volatility, while also minimizing foreign dependence and supply chain risk.

Mukund Karanjikar, chief executive officer of CleanJoule. Photo courtesy of CleanJoule.

In 2012, CleanJoule was awarded a multi-year contract by the US government to develop 100% SAF for military use. In May 2023, the company announced a $50 million investment round led by the principals of US private equity firm Indigo Partners. Along with Indigo, CleanJoule is also backed by Cleanhill Partners,

GenZero, Frontier Airlines Inc., Wizz Air Holdings Plc, and Volaris Group Inc.

Karanjikar spoke to BNEF at the Farnborough International Airshow in July. The following comments have been edited for length and clarity.

Why the focus on SAF?

If you want to make a meaningful impact on a hard-to-decarbonize sector like aviation — and long-haul transport — then it means energy dense, hydrocarbon light liquids that are produced using renewable feedstock. That is the only real, credible near-term option to decarbonize aviation. If the industry requires a 65% contribution from SAF but allows only 50% blendability, the math doesn't work. We have to go 100% SAF and not 50%. The currently approved pathways are all limited to 50%.

What approach did you take?

We went to the white board back in 2012 and said "how do you enable full performance SAF?" If you chart out how the SAF pie chart looks in terms of compositional aspects, you have iso-alkanes, n-alkanes, cyclo-alkanes and aromatics.

The problem is that petroleum-based jet fuel is a fraction of crude oil boiled between two temperatures and there is no way to separate the various molecules further. The challenge is that when you have aromatics in it, you have particulate matter formation, you have near-area pollution and you have contrails because you have particulate matter in the upper atmosphere – so non-CO2 emissions. Iso-alkanes and n-alkanes are largely where everybody is focused. It's what I call a nail and hammer approach, where the hammer is the technology and the nail is aviation sustainability. Whether it comes to Fischer-Tropsch or ATJ, which is alcohol-to-jet, or HEFA [hydroprocessed esters and fatty acids], all of these pathways produce n- and iso-alkanes.

They're inadequate because the density is limited to 0.75, so how much mass per unit volume. The minimum density required to make it above the ASTM D4054 approval threshold is 0.775. That's the reason those pathways require 50% blendability. It simply wouldn't pass the qualification to be sold; it has to be blended with petroleum crude-based Jet A that weighs 0.8.

Our approach was let's focus on producing cyclo-alkanes from the very beginning because they weigh greater than 0.82. We took a fundamentally different approach from the very beginning toward full-performance 100% SAF.

Can you describe the process again from feedstock to SAF?

Forestry residue comes in. You have a simple chemical process that makes it into cellulose — that's the feedstock. That goes into a biochemical processing unit similar to producing ethanol, but instead of producing ethanol we produce olefins. The difference is ethanol still has an oxygen in it.

If you go back to a super high level, biomass comes with a molecular formula of CH2O — one carbon, two hydrogen, one oxygen. Fuel, when it's burned, is only one carbon and two hydrogens. You want to deoxygenate that biomass in the most efficient manner. All the processes do exactly that. Some, like us, do it extremely efficiently, others are a bit more inefficient.

Olefin is a material that has no oxygen in it. We make it directly in the bioreactor. The bioreactor operates at room temperature and atmospheric pressure — so fairly benign conditions and you pick out all the oxygen through novel biology.

Now you have these olefins that go into a second proprietary unit of operation that puts the olefins together with unprecedented carbon efficiency. That's important because when a ton of feedstock comes in, what really matters is how much in kilogram of fuel made makes it into the wing, otherwise you are a hydrocarbon company. In our

case, everything that comes in, we lose all oxygen in the bioreactor and it's very close to the theoretical carbon yield.

How do we get to 100%? We produce predominately cyclo-alkanes so we are well above the density threshold.

And the feedstock is biomass?

We use waste biomass – so forestry residue, agricultural residue, woody biomass of any kind. If you are to make meaningful quantities, you will have to use waste biomass because that's the only resource that's available in the quantities the industry needs.

If you look at what happened in America, the pulp and paper industry was a fledgling industry in the 60s and 70s and up into the 80s. Then Latin American pulp became a lot cheaper and an entire industry abandoned their established plans. If you go back and rejuvenate that infrastructure, you can make billions of gallons of SAF.

That industry already knows how to aggregate vast amounts of biomass, how to run centralized processing facilities, and how to convert that into pulp. Pulp is nothing more than cellulose. Add one more enzyme and you get the feedstock for our process pathway. The value chains are pre-established. We can bring the pulp and paper industry back to life and make it into SAF as a new industry.

What about access to feedstock? Isn't it difficult when the feedstock is so dispersed?

If you want supply chain security and resilience, distributed manufacturing is the way to go. Distributed manufacturing coupled with local aggregation of feedstock results in manufacturing SAF at the scale the industry demands. That's the way the next generation industry has to take effect.

Where are you on the timeline?

We are running a pilot plant already, which is essentially a version where each part of our operations is industrial in nature. We have already made thousands of gallons for our primary customer and those have been sent, qualified and used. We are currently setting up our first industrial demonstration plant, which will serve as a blueprint for our first commercial manufacturing plant that is slated to come into full operation by 2030.

You've received backing from the US government to develop SAF for military purposes. What has that meant for CleanJoule?

We've had many years of work with the US Department of Defense. They have a large fleet and they are a substantial purchaser of JP8, the military version of Jet A, the petroleum-based jet fuel. We have worked together with them to accelerate the development of CycloSAF to get to a certain scale.

The three airlines that have invested in us, they walk the walk not just talk the talk. The CEO of Frontier Airlines puts it the best. He says "I am a firm believer in the decarbonization of aviation and SAF is here to stay and more will come and if I'm willing to sign an offtake agreement with you, which personifies my commitment, then I should help you to enable that future, not to just wait. I want to invest in you."

Are you optimistic the aviation industry can meet its 2050 goals?

I am inherently optimistic. The answer is energy dense liquid hydrocarbons that are sustainably produced. The other option is: don't do anything sustainable, which is not on the table anymore. But if you want a growing and sustainable aviation industry long into the future, then SAF is your only solution, and SAF doesn't come in the same colors and flavors everywhere. There are

multiple process pathways, there are multiple companies, there are a lot of large corporations that have made investments in production pathways.

Many will succeed because the demand for fuel as air travel continues to grow is meaningful. 2050 will not happen in a vacuum. We're not going to fall asleep and wake up in 2050 with a decarbonized aviation industry. A lot of effort, a lot of commitment from all factions from the entire industrial establishment — the governments around the world — all will need to play a key and pivotal role in enabling the 2050 vision.

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