Fusion Firm Backed by Google Hopes for Mid-Decade Milestone: BNEF Q&A

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TAE Technologies Inc., a nuclear fusion startup backed by Alphabet Inc.'s Google, Chevron Corp. and Japan's Sumitomo Corp., hopes to see an "essential milestone" on its path to build a commercial fusion reactor by the middle of this decade.

TAE's efforts received a kickstart last month when US oil major Chevron invested in the California-based company alongside long-term partner Google and Sumitomo as the fusion startup secured $250 million in its latest funding round. The injection of funds will allow TAE to build the next iteration of its hydrogen-boron fusion reactor.

"In about two years or so we should have that off the ground and begin first operations with first plasma," Michl Binderbauer, TAE's chief executive officer, told BloombergNEF in an interview. "By around mid-decade, we hope to achieve the essential milestone validating the net energy capability of our technology."

TAE's fifth-generation reactor, known as Norman, was unveiled in 2017. The reactor was designed to keep plasma stable at 30 million degrees Celsius. TAE, which counts former US Energy Secretary Ernest Moniz and former General Electric Co. Chief Executive Officer Jeffrey Immelt among its board members, says Norman has been able to sustain stable plasma at more than 75 million degrees Celsius.

The recently closed Series G-2 financing round will help TAE fund the construction of its next reactor, named Copernicus. The reactor, which will be built in a 100,000-square-foot facility in Irvine, California, will be designed to demonstrate that it can achieve net energy generation. After Copernicus, TAE plans to build a prototype commercially scalable fusion reactor called Da Vinci.

TAE's advances come as momentum builds around fusion, particularly among investors. In particular, the industry says it is encouraged by the number of different sources of funding for fusion, and the increasing variety of approaches to the technology adopted by its leading developers.

According to a report published last month by the Fusion Industry Association, private fusion companies raised at least $2.8 billion in the last 12 months, bringing total private investment in the technology to more than $4.7 billion.

"It's not just one type of funder," said Andrew Holland, chief executive officer of the Washington, D.C.-based Fusion Industry Association. "It's not just the Silicon Valley venture capitalist. It's a whole range of different folks. One (area of funding) that we haven't gotten too much into yet is the Wall Street capital markets and we're starting to try and figure what we need to do to attract those."

According to the association, some of the most notable investments in fusion in the past year include $1.8 billion into Massachusetts-based Commonwealth Fusion Systems LLC, $500 million to Everett, Washington-based Helion Energy Inc. and several smaller investments over $100 million. In June, Zap Energy Inc. said it had closed on $160 million in a Series C funding round.

"It used to be until this year that most companies, like most investors, chose one horse and they bet on that one to win," Holland said. "But now it seems like there are more companies, and more investors, that are betting across the industry. That's a real signal that it's not just that we believe that this one company has a great idea and a good team, but that we believe fusion is coming and we want to make sure that we're involved in all of it."

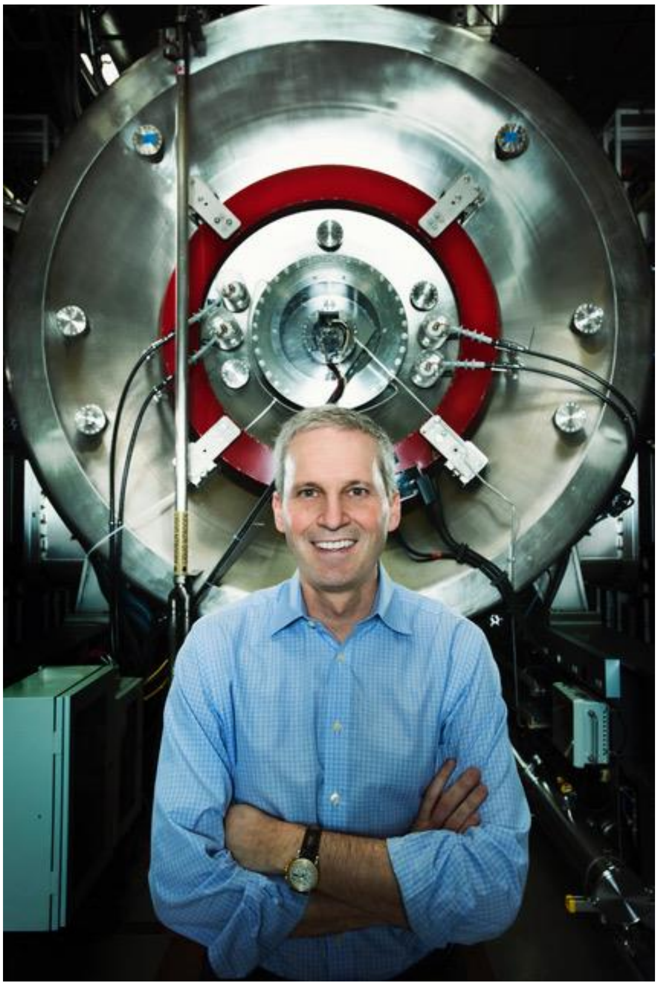
TAE's Binderbauer spoke to BNEF in late July. The following transcript has been edited for length and clarity.

Q: The old joke in the industry is that fusion is a wonderful technology that's always 30 years in the future. Why is fusion so hard?

A: It's hard because basically we're trying to recreate the same extreme conditions that occur in our sun, but without the benefit of the sun's massive gravity. It's a very different environment that we have in a lab on earth. As a result, terrestrially, we have to get to temperatures much higher than in the core of the sun, which is about 15 million degrees Celsius. The entry point for terrestrial fusion is about 100 million (degrees Celsius) and goes up from there. And then you want to hold it together at those conditions for a sustained period of time, while somewhere around it there is room temperature.

Think of simple physics or simple science. Cold and hot, they mix. Plasma doesn't like to stay hot, and the environment around it wants to suck that heat out -- so there's a lot of ways for heat to escape and temperatures to cool. What we've struggled with for 50 years as a field is how to insulate the plasma and keep it exactly right where we want it, so that it happily reacts and produces energy. Getting this to happen for an instant is easier to do. Holding it there stably, that's where the ballgame gets really difficult.

Q: I get the sense that there's been a turning point in fusion in terms of the interest in the technology and the financing of it over even just the past year. Can you talk a little bit about that?



Michl Binderbauer, chief executive officer of TAE Technologies Inc. Photo courtesy of TAE Technologies.

A: This is an era we've been working toward for decades. There's a confluence between the science being very well understood and at the same time the technology being mature enough to meet the scientific challenge. We touched earlier on the astronomical temperatures required to achieve fusion. That's just one facet of the challenge. You've also got to get fickle plasma hot, and then keep it hot and well-confined. In our concept -- a form of magnetic confinement fusion -- one needs lots of control systems that continuously monitor and readjust subsystems, ideally in real time. Real time in these environments means doing feedback in thousandths-of-a-second timescales. That gets into the realm where digital latencies can be too long.

Now we have faster electronics. We've got faster, more efficient algorithms. All those technologies are just maturing to the point where all that is needed becomes possible. What you find now is a number of us are realizing that we understand the science well enough, and we've gotten our tools to actually contain the beast, so to speak. What you see is a high degree of confidence that over the next eight to 10 years, one, or maybe multiple companies, are going to crack that nut. I think this isn't lost on the investment world. I think they understand and see on diligence, that performance is improving to the cusp of fruition.

Q: TAE's approach to fusion is fusing a hydrogen proton with boron as opposed to deuterium and tritium. What is the advantage to your approach and what are some of the challenges?

A: TAE started with the end result in mind. We considered what an ideal power plant would actually look like. What would a utility want? Obviously, low cost or competitive costs with current generation technologies. If you think practicality, you don't want to have to have a hundred PhDs in the control room. While the capabilities need to be robust, you want the footprint to be compact, because that impacts cost and that also creates easier economies of scale. You also want fuel and other materials to be safe -- obviously not radioactive, or in any way impacting the environment.

The one fuel cycle that checks all those boxes is hydrogen-boron also known as proton-boron or p-B11. Along with the many benefits, the difficulty with it is that it requires higher burn temperatures. We were talking earlier about 100 million degrees being the entry point for terrestrial fusion. That is with the deuterium-tritium or D-T fuel cycle. About a billion degrees is the entry point for hydrogen-boron fusion -- so a factor of eight to 10 higher than where one needs to be for tritium-based fusion. You're then in a zone where it may seem implausible or impossible but CERN's Large Hadron Collider has achieved temperatures over 5 trillion degrees Celsius -- for non-fusion purposes -- so 1 billion is a number that we believe is within reach.

The reason we chose hydrogen-boron is for that end in mind. Boron is ubiquitous around the world, there's no shortage and it's not radioactive. When hydrogen and boron fuse, they make helium. Helium has no impact on anything as it is chemically inert. There is no radioactivity in the primary cycle. The terrestrial supply abundance of boron is something like 100,000 years' worth. It's mined today by the metric ton and used in detergents, soaps, and cleaning products. We wouldn't even splice a lot of that industrial use away for energy production because hydrogen-boron fusion doesn't require a lot of material.

The challenge again is that you have to get to higher performance conditions. You have to develop a better mousetrap -- something that can hold the material together under the right conditions, which we believe our technology will be capable of.

Q: How close are you to generating more energy from a reaction than the energy consumed? What is the likely timeline?

A: We just announced that we can reach temperatures of around 75 million degrees Celsius with our current machine, called Norman. Our plasma is totally stable; it's happy to sit there at those conditions, but it's not a high enough temperature to begin cooking fuel. The next machine, which will be called Copernicus, is intended to showcase that. It's going to operate between 100 and 150 million degrees Celsius to demonstrate the viability of net energy generation at the entry fuel conditions.

We plan for that to happen by around mid-decade -- a milestone of having more energy coming out than is being consumed. From there we plan to build a full prototype running on hydrogen-boron. If everything goes well, this machine, as currently envisioned, would actually send electrons out to the grid in a fully connected installation by around the end of the decade.

Q: You've got a diverse group of investors. You've got Google, Sumitomo and Chevron. What does that group bring to the table for you?

A: Let's say it's the early 2030s and our aims have been met. We can make net energy, we can actually make electricity at competitive rates. Now, how do you scale that into a world that is starved for power? Well, you need partners. You need a supply chain developed with robust scalability on the industrial side, and that's not going to come from TAE.

We engineer, design, and create technology but we're not going to take fusion power plants into the market by ourselves. We will do this with partners. So, you're now looking for the larger industrial players that can scale our technology at a high quality of production -- the GEs, the Siemens, the Sumitomos of the world. We're also teaming with the energy companies that understand that part of the business and have the connectivity. When you look at our financing today, you'll see that we've become much more strategic. In addition to the venture capitalists who shared our vision, we've identified institutional powerhouses who are positioned to help us develop, commercialize, and serve the massive global need for electricity with our technology. In other words, we are looking to develop partnerships that can help us scale.

Q: Can you talk a little bit more about what the latest fundraising does for you? What capability does that give you?

A: This latest round of funding allows us to put the capital in play to build our sixth-generation machine called Copernicus. In about two years or so we should have that off the ground and begin first operations with first plasma. By around mid-decade, we hope to achieve the essential milestone validating the net energy capability of our technology.

Q: Is Copernicus the reactor that you will take into the commercial environment?

A: Copernicus is going to produce more heat, if you will, or energy coming out than what we feed in. Post Copernicus, the next machine will be called Da Vinci. That's the device that will then take it to a full power plant. Instead of heat coming out at the end, electrons will come out and they will go directly from the reactor onto the grid.

Q: In a recent report, the Fusion Industry Association said over $4.7 billion has been invested in the global fusion industry and that something like $2.7 billion had been invested in the past 12 months alone. Additionally, eight new fusion companies have entered the market. Is there a risk of a fusion bubble?

A: I ask myself that sometimes. It's a really incredible time for the industry. I'm very glad -- as someone who believes that the technology can succeed and solve our energy problems -- for the sake of humanity. More shots on goal are what we need. The diversified shots on goal that the private sector is bringing gives us a much better chance of cracking the nut. The publicly funded programs have over time become more narrow in the kind of concepts that they have worked on. But it's just like in investments: a portfolio approach tends to do better than if you just invest in one or very few targets.

Is it a bit overheated? I don't think it is at the moment. What we're seeing is that these are all good ideas that should see the light of day and get tested. Are all of them going to succeed? I can't answer that. I don't know in detail what some people are trying to do. But I would think that there is more than one way to solve the fusion riddle.

When you think about what we need, we have to solve this problem. This is part of our defining moment for humanity. We want to make sure we get beyond hydrocarbons in energy generation. We want to make sure we find an alternative carbon-free baseload power source that can complement renewables and can carry us into an era of clean and abundant energy. I think technology like ours is primed to do just that.

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