This is an edited interview with TAE CEO Michl Binderbauer for TAE's Good Clean Energy podcast. Press may quote from this document in coverage.

How does TAE's Field-Reversed Configuration (FRC) differ from other fusion configurations?

The FRC solves every ideal sort of metric you would want to solve for in terms of a fusion power plant. When you think of a power plant, you want one that robustly runs all the time, is easy to maintain, is cost-effective and runs at the current rates of expense so utilities can competitively introduce the technology in the market. The FRC is unique in that you don't use outside magnets to create the majority of the magnetic field. What that means is that you don't have to deploy a lot of big expensive magnets that are hard to maintain. The FRC is confined from within. The plasma makes its own magnetic field and that field cages it. In that sense, it's ideal. Less gear, you need less material, less cumbersome manufacturing, less cost, less maintenance. The thought then obviously is, Why isn't everyone doing it? The reason is it's harder to do when the plasma makes its own current and makes its own magnetic field and cages itself. Just think what happens if the plasma does something slightly different than what we want it to do. It's its own sort of dynamic beast. It's like an unwieldy child. You tell the little kid don't go over there, but they go there. The plasma in an FRC kind of behaves like that. So what you have to learn is how to manipulate that through feedback control, coercing and cajoling it into behaving the right way and that's been exceedingly hard.

What are some challenges to working with the FRC?

One of the problems is how to start the FRC. Historically, people had only one solution, which was sort of use a big sledgehammer. You create two blobs of plasma and accelerate them. They collide and the collision creates a compound object which becomes the FRC.

The disadvantage with this is because it's a bit brute force, you cannot quite control the intermediate process. In fact, I would argue it's so quick, you can't really control it at all. That's one thing, the startup. And then the harder part is how do you keep it operationally in the right condition throughout its life cycle when, as I said earlier, it may want to get unwieldy. And then more importantly, you only need this collision process once.

Assuming you run a power plant steady state – which is what we're trying to do – you start it once a year, let's say. It's like you have a car motor, and you run that motor once, and then the car runs for a year but you still have to pay for the electric starter motor, the extra battery, all this kind of stuff, and you rarely, if ever, use it.

For the operation of a power plant that runs 24/7 [with an FRC] ...you're paying a price for the fact that for a few thousandths of a second at its start you needed all that, but then you don't need it anymore. And you can't just magically disconnect it. These are big systems. They're part of the vacuum environment. So it's not ideal. However that was the one thing that worked and we made that work better than anybody else that I know in the field. Reliable, predictable, controllable, adjustable. And that worked for us for a long time. The entire history of TAE was built on that, but we always looked for a better way to start an FRC. Less violent, more controllable, more tunable, and none of this end gear that you need. You can make the machine more compact, less expensive and get rid of all this starter stuff and intermediate components.

How has TAE revolutionized the FRC?

This is what we're celebrating right now. We actually accomplished this — a quest decades in the making, two decades roughly for TAE in its company's history. And then prior to that, a couple of decades under Department of Energy leadership and people around the world trying to make an FRC more elegant, more controllable, more practical. It's a very hard problem. And it turns out once you solve it the way we solved it, not only do you solve the starter problem but you make the caging better and more controllable. Now if you scale up to a power plant, you haven't only solved what happens in those thousandths of a second initially, you've now brought yourself serious improvements for the entire rest of the lifetime of this system because you got rid of all this equipment. Upfront it’s a much lower cost of materials to build a functional reactor. It's also a lot more efficient so more power will be sent out to the grid.

This is an edited interview with TAE Director of Diagnostics Thomas Roche for TAE's Good Clean Energy podcast. Press may quote from this document in coverage.

How did Norman, TAE’s fifth-generation machine, create and sustain plasma?

Norman is what is called a Field-Reversed Configuration (FRC) fusion reactor device. And what it does is it creates a ball of plasma that a current flows in that causes it to create these closed magnetic-field structures. And these closed field lines make the imposed magnetic field reverse, that's why it's called a Field-Reversed Configuration. The current is sustained by the injection of neutral beams.

Neutral beams are basically hydrogen atoms that are shot at a very high velocity, and since they're neutral, they're able to move past the magnetic field. When they interact with the plasma, they get ionized and their velocity carries in current. This current keeps the magnetic field reversed and heats the plasma as well. So as the plasma gets hotter and hotter, we can increase the magnetic field and reach fusion-relevant temperatures and the hydrogen atoms start to fuse with each other.

The Norman device had what we call the formation sections. In technical terms, they're a theta pinch coil. And we used theta pinch coils on each side that push the plasma and accelerate it to a very high velocity of about 300 kilometers per second. This generates two FRC plasmas in a very fast process using pulsed power. These FRC smoke rings move towards each other in the center of our confinement vessel and collide into one larger FRC that has a very high temperature and a relatively high density. This density is now high enough for the neutral beams to be captured.

How did Norman turn into Norm?

I wrote an experiment where I said, Okay, we would try to operate the machine without formation sections and with a couple other things. All we needed was the neutral beams and the right set of conditions of the initial seed plasma to get the field to reverse without using the theta pinch coils. I remember having my jaw drop that day. I was kind of expecting the experiment to be interesting, but I never thought that it would lead us to the state that we're in now. It turned out that we were already in the conditions that were necessary to generate Field-Reversed Configurations just by neutral beam injection alone.

This isn't the first time people have tried to do this. There's been quite a few attempts at injecting particle beams and generating reverse fields. There have been experiments that date back all the way to the ‘70s where this was attempted. But at TAE, we've developed the beam technology that has allowed us to enter into the space where this is possible. And we've done it long enough now that we have a really good theoretical understanding of the process, how it works and why some of the earlier trials didn't work. And having figured all that out means that TAE’s next reactor, Copernicus, will have more power and more beam injection.

What was the peak performance achievement for Norman versus the same for Norm in terms of temperature and confinement time?

We've at least doubled all those parameters in the Norm regime over Norman. Now it's not necessarily just because we removed hardware, but we got better and better at running the machine along the way. So part of it was the simplification of the machine and being able to do things more compact so it minimized losses and impurities. But the other part was just becoming proficient at the operation of the machine over time.

In terms of cost of goods, what are we saving by taking all the formation ends off and the things that power it and the diagnostics and so forth?

That's probably about 25 percent of the cost of an experimental vessel. It's a significant reduction in complexity because the formation sections — the theta pinch coils — require pulsed power. That means you need a huge amount of energy storage and quick delivery of it. Those kinds of parts are complicated and it takes a lot of engineering to get them to work. And they degrade over time because they have to produce these huge currents and deliver a lot of power. I'm excited that we're now able to do what people have tried to do for decades and do it efficiently with a clear understanding of the process and how it will bring us to a very efficient and very economical fusion reactor in the future.