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RealClear Energy

Zabrina Johal: Is the U.S. Losing the Fusion Energy Race?

By Staff
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This article is adapted from an interview that energy expert Scott Tinker conducted with Zabrina Johal at RealClear's 2024 Energy Future Forum. Johal is the Senior Director of Strategic Development at General Atomics.

Scott Tinker
If I remember correctly, you grew up in Montana and until you were 18 had never even gotten on an airplane. Then your next job was running a nuclear reactor on an aircraft carrier, right? Did I miss anything in between?

Zabrina Johal
Just a few things. Highlights? Any military folks here will appreciate this: Officer Candidate School and getting my head shaved was definitely a highlight. Tomahawk Strike operations on my first ship was another. Then, of course, operating the reactor.

Scott Tinker
So that prepared you for a career in nuclear energy. I'd like to focus on a particular type of nuclear energy—fusion. What is fusion energy?

Zabrina Johal
If you recall the periodic table, fusion involves hydrogen, the lightest element. Fission involves uranium, the heaviest naturally occurring element. Fusion is the process of two nuclei coming together, while fission is the process where nuclei split.

In the U.S., 20% of our electricity comes from fission, that's nuclear power, and it provides a full 50% of our clean electricity, which is phenomenal. Fission operates through a chain reaction: a heavy element splits and releases energy and neutrons, and those neutrons keep the reaction going. Fission is also what powers our nuclear Navy, which puts us ahead of many other nations.

Fusion is what powers the sun and stars. In space, powerful gravitational fields cause light elements to fuse, converting mass into energy. Fusion is a million times more power-dense than fossil fuel combustion because it involves nuclear reactions, not chemical bonds. When we create energy from chemical reactions, it's the electrons changing their bonds and arrangements. But with fusion, we're dealing with the nucleus, where there are heavier particles and much stronger bonds, which is what releases massive amounts of energy.

Scott Tinker
With fission, there's concern over reactor safety and control. Does fusion carry the same risks?

With fission, there's concern over reactor safety and control. Does fusion carry the same risks?

Zabrina Johal
I love both fission and fusion, but let's talk about safety for a minute. It's true that almost 20,000 people died during the Fukushima disaster, but that was all from the tsunami. None died from the reactor incident. Before Fukushima, I was working to develop nuclear energy with Japan, but the disaster stalled all those efforts. They shut down most of their reactors, and it's still a challenge to get them back online even though they need that clean energy.

It's worth noting that more people have died from solar energy—falling off roofs during installation or maintenance—than from nuclear accidents. Fission gets a bad reputation for safety, but it's been encouraging to see more realistic conversations about how we incorporate different energy sources.

Fission operates with a chain reaction, and if that reaction isn't controlled, there's a potential for escalation. The reactors we build today have safeguards to prevent that. Fusion, however, doesn't rely on the same kind of chain reaction. It's a much more technical process, one that scientists have been pursuing since the 1920s.

Here on Earth, we don't have the large gravitational fields that stars do, so we have to create a plasma—the fourth state of matter. Most of the universe exists in this state, but here we usually only learn about solids, liquids, and gases. Plasma is different from the other three because the electrons are no longer bound to the nucleus. To achieve fusion, we have to free those electrons by heating and use magnets to control the plasma. The temperatures need to be extremely high—about 100 million degrees, or ten times hotter than the sun. If you lose all site power, such as in a situation like Fukushima, the magnets stop working and the plasma just dissipates, making fusion inherently safe.

Scott Tinker
So it's magnetic confinement, right?

Zabrina Johal
Yes. There's also inertial confinement. You may have heard about the National Ignition Facility in California. About a year and a half ago, they achieved ignition for the first time, meaning they put energy into plasma and got more energy out. They've done it five more times since then, using inertial confinement. It's proof that the laws of physics are sound, and we can achieve fusion energy. There's still a lot of engineering work needed, but this is a huge milestone.

Scott Tinker
So, where are we now? Is there a strategic plan for fusion in the U.S.?

Zabrina Johal
I think a lot about how the Department of Energy is funding nuclear research and development. For fusion, much of the financial risk has been left to private developers, which has set us back compared to other countries. It's estimated that it will cost about $4 billion to move from concept to commercialization. In the U.S., private companies face significant financial, regulatory, and technical risks. Look at NuScale, a private fission developer—they've spent over $600 million, likely closer to a billion, just dealing with regulatory costs before even building anything.

Meanwhile, countries like China are moving forward with state-funded programs. The U.S. was originally the leader in nuclear energy. We put reactors on submarines and commercialized them for civilian use. We can do it again.

On the fusion side, we've never generated electricity from it. The U.S. fusion budget is only about $750 million a year—nowhere near enough. However, there's been over $6 billion in private fusion investment. People see potential because of advancements in enabling technologies. Fusion is often called the 'Holy Grail' of energy. The fuel is abundant—deuterium from seawater and tritium that we can breed from lithium inside the reactor.

It's safe, as we've discussed, but there are still hurdles. In California, there's a moratorium on new fission builds due to waste concerns. However, spent nuclear fuel is not waste—it's an asset. We currently only use about 5% of the energy in uranium before we store it. If we can use more of that energy, the waste issue diminishes.

But there's also a moratorium on reprocessing, so we aren't reprocessing spent fission fuel either. With fusion, because of the enabling technologies and because we now have private investment—China being a big player—we'll likely see fusion technology succeed within the next 15 years.

General Secretary Gorbachev approached President Reagan in the mid-1980s. He proposed that we bring all our resources and funding together for a fusion energy project. That project is happening today. Thirty-five nations are collaborating in what might be the largest scientific collaboration in history—perhaps only second to the International Space Station. It's called ITER, and it's under construction in southern France. It involves Russia, China, Korea, Japan, India, and the EU—making up 35 total nations. They just released a baseline stating they aim for deuterium-tritium operations by 2038.

The goal of this machine is to prove fusion's feasibility. You can imagine the challenges—35 nations, all with different technology, dividing up tasks, and dealing with diplomatic issues. What we've seen recently is China going out on its own. They're still a partner in ITER, but they're also putting significant funding into their domestic fusion energy programs. Their goal is to train over a thousand plasma physicists. They plan to have a prototype fusion reactor generating electricity by 2035.

Scott Tinker
Has the U.S. been leading this effort, or are we falling behind, especially if we can't get past the budget hurdles?

Zabrina Johal
We have very little funding for it. About two years ago, the White House announced a bold, ten-year vision for achieving fusion energy. They allocated some funds to private fusion companies, selecting eight different concepts. These companies need to bring in over half of the funding as a cost-share, but it's not much compared to what's needed.

Scott Tinker
When you say 2035, that's not commercial fusion, correct? Or is it?

Zabrina Johal
That's a prototype fusion reactor generating electricity. It'll take another five years or so to get to commercial reactors. Keep in mind, China is currently building around 30 nuclear fission reactors.

Scott Tinker
Big ones, right?

Zabrina Johal
Yes, at gigawatt scale. They're making it happen, because they have the nuclear workforce that we don't have anymore. Here's an idea for the U.S.: South Korea recently built four nuclear plants in the Middle East —the Barakah plants—on budget and schedule. If we're serious about solving our challenges, why not bring the Koreans here to build some plants, train our workforce, and get nuclear plants built today? This isn't a ten-year proposition. This is something we can do now.

Scott Tinker
Let me ask you to look into your crystal ball. You've been in this field a long time. Where do you think commercial fusion will happen first, and when?

Zabrina Johal
I think it'll be China in 2035, unless we can pool our resources, be smart, and tap into the entrepreneurial spirit that we know we have. We could still make it happen here.

Scott Tinker
General Atomics has been a nuclear pioneer. We haven't heard much about your high-temperature gas reactor. Can you talk about that?

Zabrina Johal
That was a fission reactor concept. I helped develop it back in 2009 when we recognized the need for advanced nuclear power. The concept used high-temperature helium gas directly from the reactor core, rather than a steam generator and Rankine cycle. It sent the helium straight through to the turbine blades, through a Brayton cycle. This made it 40% more efficient than a pressurized water fission reactor. It was a small modular reactor—265 megawatts electric.

When we started proposing it for development, we knew it would cost around $4 billion to get to commercialization, so it needed to be a government-supported venture. At the time, there were around 60 other advanced nuclear concepts, all of them being funded at small levels, except for two: TerraPower, backed by Bill Gates, and X-Energy. Both of those are still around. Bill Gates has taken on a lot of the financial and regulatory risks on his own—few people besides him could do that. Years ago, he planned to qualify his fuel in China, but the Trump administration trade restrictions ended up costing him hundreds of millions of dollars. That's the kind of risk involved in commercializing new nuclear technologies.

Scott Tinker
So we're talking about high-density, zero-emissions energy, small land footprints, abundant fuel sources. How do we communicate these benefits and motivate action?

Zabrina Johal
I'd say fusion energy is 100% feasible. It all comes down to how serious we get about it and how much money we're willing to invest. With all the challenges around generating electricity, why not focus on something that works when the sun isn't shining and the wind isn't blowing—and is carbon-free? The enabling technologies are crucial—high-temperature superconducting magnets, for instance. They allow us to generate the same magnetic field in a much smaller footprint. Materials research is also critical—both fission and fusion reactors are bombarded with energetic neutrons and operate at extremely high temperatures.

And then there's the big one—data collection and machine learning. Plasmas are complex, with free electrons and ions zooming around. To be able to model and simulate those behaviors, and predict outcomes before experimentation, requires enormous computing power, but doing it brings us much closer to solving one of humanity's grand challenges.

Scott Tinker
You've mentioned magnets a few times—are we able to mine the materials we need to make this happen?

Zabrina Johal
Rare earth elements are definitely an issue. General Atomics has a project in Wyoming showing we can mine and separate these minerals with high efficiency. This is something our nation needs to focus on. Regarding magnets, General Atomics is building the central solenoid magnet for ITER—a tokamak project. Imagine a hollow donut, and down the center, we stack six huge electromagnets. When it's complete, this low-temperature superconducting magnet will weigh 1,000 tons and stand 49 feet tall. It will be the largest, most powerful pulsed electromagnet in history, and we're shipping it to France as the elements of it are completed.

Scott Tinker
Final question—what makes you hopeful for the future, especially for your kids?

Zabrina Johal
Something that concerns me is the sensationalism around climate change. Kids hear it and take it to heart, and I'm troubled by some of the rhetoric used to create urgency—it affects our young ones deeply. But what gives me hope is seeing how smart the younger generation is. I was the first woman on my ship out of Pearl Harbor, and I think a lot about the need for diversity in STEM, and role models that earlier generations didn't have. Seeing younger generations embrace that diversity and pursue STEM careers without the same barriers gives me a lot of hope.

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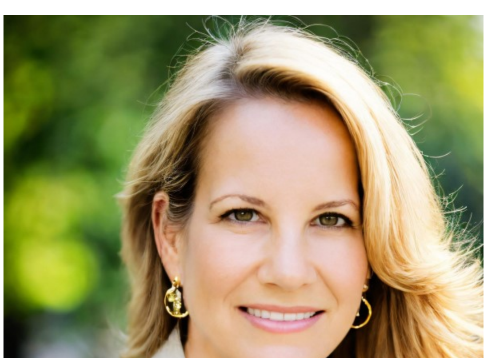

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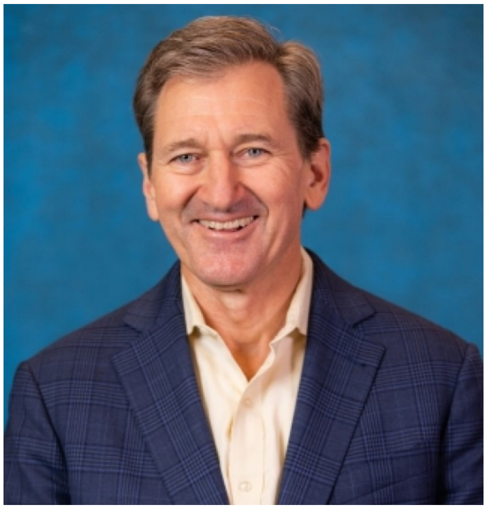

Scott Tinker is Director Emeritus of the Bureau of Economic Geology and the Chairman of Switch Energy Alliance.

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