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WHY FUSION AND WHY NOW?

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Andrew started this with a discussion about energy, and I do a lot of public lectures about fusion, but I actually start with energy first also.

It's an economic argument. A scientist always asks "why?" This trend, or non-trend—this mythical energy transition that we keep speaking about—is not actually happening. Our energy mixture is almost the same as it was 50 years ago. It's changed only by 8%. That's interesting. Why?

People are confused by energy, yet it's the most important commodity, though I never even call it a commodity in these talks, I call it a rootstock. What do I mean by this? In our modern economy, its rootstock is energy.

How do you prove this? For example, you can go back over the last 50 years of the United States economy, and you look at the ratio of the amount of money that we spend on energy to our GDP. While the absolute growth of GDP has increased by about a factor of 20, that ratio is almost identical to what it was 50 years ago.

What do you think the number is? What is the ratio of GDP to our expenditure on energy? Is it 2? 10? 50? A hundred?

This is, I think, the most important number that we have. The answer is interesting.

It's 15. Wow!

When I look at the United States economy—in fact, any advanced Western civilization—I look at what we have built, and I call it "the economic amplifier." Everything that we do that produces something for us uses energy. That's why I call it a rootstock. We have built an extraordinary amplifier out of our economy. When you think of a factor of 15 increase, holy wow. That's an amazing engine that we have built.

But it also tells you why things haven't changed. It's because any amplifier has to have an input signal. If you stop the signal, the amplifier dies. It has to have something to amplify. You cannot stop using energy in business. But you also cannot let energy have arbitrary costs.

We've seen things today that are amazing, about personal medical cases and changes to the lives

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of people. But I think, as a *species* on the planet Earth, we are taking a test right now, a moral test. The moral test is the following: because energy use is directly linked to economic well-being, energy use is the leading indicator of *human* well-being. And we've built this relationship over a very long time. Look at all the indices of human existence—everything gets better when you use more energy.

But the very thing that's given us this well-being is essentially fossil fuels—we're on a one-way street to something where we don't know what's going to happen, but it's probably not going to be good.

What do we do? It's a dilemma, and for the following reason: we can't stop using energy, because that's what makes people healthy. But we have to change.

That's why we'll see fission, fusion, or geothermal emerge in the long run. As a physicist, I can tell you those are three essentially inexhaustible sources of green energy on the planet Earth. This is what motivates me to work in this field, and what's motivating more and more young people to come into our field as well. And we're now at a really amazing inflection point.

So, on the front lines, where are we? Fusion has been fantastic—talk about a new discipline. When my mother was born, we didn't know how stars worked, the process we call fusion. It hasn't been around that long. But we hit an inflection point of people realizing that this is an incredibly worthy scientific goal, like mapping the human genome. We're at the point of thinking, "Can we actually adapt this into a new energy source that changes our basic relationship to energy?"

For reasons I don't have time to explain to you today, fusion is even more diversified than what Andrew has told you. It's because the science of fusion allows a staggering array of technologies—it comes from the combination of two physical parameters that must be achieved. This is why, when you see these articles about fusion, it's often confusing: "I see a laser, and I see a magnet, and I see electricity." They're actually trying to get to the science of fusion, but through very different technologies. This means that fusion already has diversification built into it.

As a scientist, I never thought I'd be working on making fusion energy a reality. I thought this was going to be something where I'd follow my predecessors. All of a sudden, we found ourselves at this place where we need to try to see if we can get this past the goal line. And what is the goal line? The goal line is not physics; the goal line is economically viable fusion energy.

Right now, what is the battle from the front lines? There's not just one company, but something like 50 to 60 startups that are trying different ways of achieving fusion. A lot of them are not going to get there. The science of fusion is hard, but even if some of these companies achieve scientifically valid fusion, they may not get there from an economic point of view.

In fact, the biggest risk right now in fusion is not the science. It's finance.

Those startups are severely underfinanced for their goal. Why is this? Part of it comes from the science of fusion. You need big shots on goal. You can't build a device that produces a few watts. You have to build these at the size of what you saw in the presentation—hundreds of millions of watts. This is really interesting from a financing point of view, because it means you have to take a large financial risk upfront, but it's sized to what you're after. If you get to the goal, you'll be replacing an $8 trillion-a-year industry, because that's the potential that fusion represents.

So how do you get there? How do you get from this starting point, and all these different ideas, to the place where we have not only one but a portfolio of successful fusion companies, building the different niches in our energy system? What could be a more important thing than doing that?

That's what motivated us to write our papers on financing fusion. In my own estimation right now, the biggest risk is the thing that the people in this room are experts in. How do you finance something like this all the way to its end goal? We will have to bring up every aspect of our ingenuity, not just the physics and technology. The more I've learned about it, the more I'm worried about it from this point of view, but it's being able to work with Andrew on this has been an extraordinary privilege.

That's the update from fusion. Again, thank you so much, Andrew, for inviting Neil and me up to the podium to speak.