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Cover Page Footnote

Caroline Bisk would like to thank her family for their support, as well as the executive board of SJEL for this wonderful experience.

Great Things Come in Small Packages: Max Effgen of Supercritical Technologies, on the Legal Context Surrounding Their Creation of the World's Smallest Power Plant

Max Effgen[†] *& Caroline Bisk*[‡]

SuperCritical Technologies is a Bremerton-based start-up that seeks to provide clean, ubiquitous, and reliable electricity to meet the world's growing energy needs. Max Effgen, co-founder and lead of Business Development, spoke about this new technology with Caroline Bisk, the Executive Content Development Editor of the Seattle Journal of Environmental Law. Caroline's questions appear in SMALL CAPS *in the interview that follows. Among many other things, Max addresses what makes their technology uniquely capable of fulfilling their mission, how energy regulation shapes many of their decisions and strategies, and why it is so important for Washington.*

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† Mr. Effgen is the Co-founder of SuperCritical Technologies. He holds a BA from the University of Michigan and an MBA from the University of Washington.

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I. LET'S TALK FIRST ABOUT THE TECHNOLOGIES AND IDEAS BEHIND SUPERCRITICAL TECHNOLOGIES. WHAT PROBLEM ARE YOU ADDRESSING?

Today, the power paradigm is that size equals efficiency. The bigger the power plant, the more efficiently you can produce power, and there's a range of technologies that can do this. Large hydro dams spin a turbine and produce power, nuclear power plants that also heat up steam to produce power. If you're concerned about emissions it's pretty hard to not advocate for nuclear power due to the potential to slash CO_2 emissions. And there's a variety of companies that are questioning the classic paradigms of large power plant energy providers. TerraPower, Helion Energy, New Scale in Portland, and even work in Kennewick at Hanford, with their huge concentration of talent at Pacific Northwest National Laboratory.

Research around the nuclear space is part of what inspired our technology. Unlike nuclear, which is steam-powered, we use CO_2 as the working fluid in a closed loop, then we heat and pressurize. There are two

reasons to use CO_2. First, it goes supercritical, a fourth state of matter with the properties of both liquid and gas, at relatively low pressure and temperature. Think of the density of water but can move with the viscosity of a gas. Second, it's known as an energy-dense working fluid. When you use super-hot, super-pressurized steam at critical, supercritical, or ultra-supercritical temperatures–what they do now in many coal-fired plants in India and China–the water has to be purer than pure, otherwise the turbines and maintenance are impacted. CO_2, because it is already a gas, does not have this purity challenge. Power plants are like jet airplanes: they only make money when they're running! And you need to balance this technology with the grid.

So, here, you have an energy-dense working fluid, denser than steam, and that means you can shrink the size of the turbine and all of the components. This is an orders-of-magnitude reduction. Our turbine wheel is only going to be sixteen centimeters, about the size of a salad plate. To compare, natural gas fired turbines that produce five megawatts would be about eight feet high and twice as long. When turbines shrink in size, they can be produced more economically. Plus our technology operates in a closed loop–avoiding thermal creep and costly maintenance, as well as nitrogen oxides, sulfur oxides, and other regulated emissions.

The cool thing about our technology is that we are a microgrid or distributive generation technology. We could site one at every substation, which is how power gets from a power plant to your home, in Seattle, and we could still be considered a small power generator. For utilities this is where it gets really exciting. Today, they forecast future energy needs and say "We need another 100 megawatt base load plant," and well, you don't just order one up. It takes three to five years. Once it's built, they don't fully need all 100 megawatts of power all the time, and running a 100 megawatt power plant at halftime costs some money. What our pitch to a utility is, we can ship you multiple power plants that you can site wherever your substations are, and you can control them remotely because we don't use steam. Steam-powered plants require an on-site operator—an old rule that predates power generation. They're unaffected by windstorms and rainstorms that could normally take out an entire neighborhood's power. They would generate their own power in a miniature plant the size of a shipping container, and you're up and running. At five MWe in size, you're just selling not just to utilities, but to other customers as well.

II. WE'RE TALKING ABOUT PUTTING POWER INTO THE POWER GRID. FOR A LITTLE CONTEXT, WHAT DOES THIS SYSTEM LOOK LIKE?

The North American power grid is the world's largest machine. It connects the United States, Canada and parts of Mexico. The US grid is broken down into four regional interconnects. Washington is part of the western interconnect, which covers the Dakotas, down to Texas, all the way over to California, and then up. By law, the amount of power supplied by grid-connected utilities must be at all times equal to 1.5 times the size of demand. So, if I want to put a thirty megawatt data center in the Georgetown neighborhood of Seattle to support new cloud computing services, that means that by federal law, Seattle City Light has to find forty-five megawatts of extra capacity. Non-grid connected utilities, known as microgrids, have to have twice the capacity because they do not have connection with other power providers. So, to support your thirty megawatt data center off grid, say in a village cooperative in Alaska, you somehow need to identify and provide an extra sixty megawatts of power, which is insane due to the capital expenditure economics involved.

III. WILL WASHINGTON BE YOUR PRIMARY MARKET ONCE YOU ARE IN A POSITION TO START CONSTRUCTING THE PLANTS?

Not necessarily. Here in Washington, investor-owned utilities are required to buy five MWe of power or less as it is considered to be small power generation, but they also have a lot of say in what they pay for it. And what they pay for it isn't very good. By that, I mean it is tough to make the economics work. Having said that, we have a technology that could make it economically viable, even for small producers who are being paid very little for the power they provide. It would not be viable to go buy a lot of one MWe diesel generators, put five together, turn them all on, and sell power to the grid. It would be very loud, with ridiculously toxic emissions coming from the diesel, and it would be super expensive just on fuel costs and maintenance alone. No one does this. But we have a technology that can avoid a lot of these problems, so now when they say, "It starts at 5.2 cents per kilowatt hour," and you say "Ok," then they are incredibly surprised. To keep this in context, the national industrial average power rate is seven cents per kWh and is expected to increase 2-4 percent per year.

When we look at the potential for returns on a five MWe or smaller device, Alaska has the best power rates in the country. They also have the highest fuel costs, but because the efficiency of our technology, Alaska would still produce the highest returns. We're actively going there to find customers and target pilot sites. Alaska has 12 percent of the world's

microgrids, and it's really starting to market itself as a microgrid center because of that 12 percent world market share. Their dominance with microgrids has to do with its size, ruggedness, it's just impractical for a village of two hundred to grid generate power. We want to build a power plant that you can site anywhere that will provide meaningful amounts of clean power – perfect for a village of two hundred people, miles away from the nearest city, for whom it would be a major obstacle to produce their own power.

IV. YOU'RE INCORPORATED IN DELAWARE, TARGETING THE MICROGRID ALASKAN MARKET—AMONG OTHERS—BUT HEADQUARTERED HERE IN BREMERTON. WHAT WAS THE DRAW FOR ESTABLISHING YOUR HEADQUARTERS LOCALLY?

It was mainly the market conditions. There are three things Washington does really well that translate into building a compact, modular power plant. First, the shipbuilding capacity. Lots of pipefitting technology and skill over in the Bremerton shipyards. Piping will be our largest material expense, and there's a lot of guys over there that know how to do it. Second is aerospace. Turbo machinery, a lot of high-end CNC capabilities.[1] Finally, there's transportation. We are building stuff that will live in shipping containers, and you have a deep water port to deliver power plants anywhere in the world. Washington's economy depends on exporting technology. We want to be a part of that story. Not just airplanes, coffee or software, but power, literally the most important commodity.

Outside the rationale for Bremerton specifically and looking more at Washington, there's a source of support that was put in by the last legislature called the Clean Energy Fund. There are conversations and debate now for a second Clean Energy Fund. These could apply to SuperCritical Technologies to help site a first unit.

One of the challenges in creating a new kind of power plant is the actual building process. I mean, we have the drawings, but it doesn't exist yet. Power is a very risk-averse market. Who wants to buy a power plant that physically does not exist? Power can be dangerous and it is highly regulated. The Clean Energy Fund was established to help bridge that gap and establish Washington as a clean technology leader.

1. Machining technology that allows you to craft a turbine wheel out of solid metal – *ed. note.*

V. WHAT ARE SOME OF THE CHALLENGES FROM THIS MARKET PERSPECTIVE HERE IN WASHINGTON?

The challenge from a market perspective is that because Washington State has the cheapest power in the world, the economic return in Washington is awful. It's a great place to build plants, but it's a terrible place to sell them. Hydro is cheap and plentiful. Earlier generations had the foresight to harness that technology. That said, Washington has on its books Initiative 937, the Energy Independence Act, and there are proposed amendments to that Act that are being discussed and negotiated right now. I-937 includes a renewable energy mandate that requires utilities to acquire a certain percentage of their energy from renewable sources. That mandate presently excludes hydro, which explains the huge growth in windmills and wind farms over in Eastern Washington. The windmills don't turn all the time. In fact, they seem to work in a sine curve. When the wind is blowing, there's no demand, when the wind is still, people need power. And you see this all the time—it's most acute in Texas. Anyway, the net impact of I-937 hasn't created new jobs here. This law passed with 52 percent of the vote in 2006 to stimulate rural economic development, create jobs, protect citizens from future price shocks, and ultimately save money for consumers, and at the same time meet the state's climate action goals. The result has basically sent a lot of money out of the country, mostly to China, to bring in these windmill power projects to eastern Washington. The state Senate is looking at this and saying, "I don't think the intent was to create an $8 billion jobs program *outside* the state of Washington."

Refocusing on Seattle, of the new growth in the United States, almost 100 percent of new growth in power production is in cloud computing centers. That's great for us at SuperCritical Technologies, because the hub of cloud computing is right here in Seattle. There's a ton of innovation happening to help address those energy needs, and Amazon and Microsoft don't want to build their own plants—they're thinking "I need thirty MW in Georgetown. But our expertise is in computing power, not power generation."

VI. YOU MENTIONED A FEW SOURCES OF STATE AID THAT HAVE ENCOURAGED YOUR EFFORTS IN WASHINGTON. ARE THERE ANY SOURCES OF FEDERAL AID THAT YOU ARE ABLE TO RELY ON?

Widening the lens, we're getting much more efficient in this country in terms of our use of power. We're regulating CO_2 emissions faster than any country in the world due to the switch from coal to natural gas, which has been happening for a while and accelerating under Obama. When we

look at other things we could do from a federal perspective, incentives come from the Department of Agriculture, the Department of Energy, and ARPA-E, an advance energy research program. The Department of Defense is looking big-time at microgrids and they want to take every military base to grid independence, so that in the event that someone tries to shut down our grid, every base can still operate. Back in Washington in both House and Senate in this new session, there has been a lot of consideration on both sides of the aisle. There does not seem to be much difference in what people are thinking about putting a structure in place so that if green technology is important to us, we can produce it here in Washington, we can incentivize our utilities to make smart investments without exporting jobs, without importing technology. Washington is one of the biggest exporters of technology in the U.S., and they're saying, hey, if we can do it with airplanes, software and coffee, why can't we do it with clean technology? How do we go and incentivize that?

VII. FIVE MEGAWATTS IS ALMOST INSIGNIFICANT BY COMPARISON WITH THE GRID. WHAT'S THE INCENTIVE TO STAY SO SMALL?

Five megawatts is as big as you can go with the least amount of regulation. This is both a federal and a state threshold. We are considering plans to eventually expand, but for now, because complying with wide-ranging regulation is expensive and we're a start-up, it's in our interest to reduce cost as much as possible.

VIII. YOU'RE CREATING CHEAPER AND CLEANER TECHNOLOGY. BUT YOUR ENERGY IS STILL DEPENDENT ON THE FUEL THAT YOU USE, AND IF THAT FUEL PRODUCES EMISSIONS, YOU CAN'T GET AROUND THE INITIAL CARBON FOOTPRINT. HOW WOULD YOU COMPARE THE FOOTPRINT OF THIS KIND OF TECHNOLOGY TO OTHER GREEN TECHNOLOGIES ON THE MARKET—WIND, SOLAR, HYDRO, NUCLEAR?

Emissions depend on your fuel source. We are a thermal cycle, so we need heat. If there's an emissions process for getting that heat, we can't get around that. But the trick becomes how you can do that more efficiently than standard technology today. The cool thing about CO_2 is that on a spreadsheet, you can get with a simple cycle turbine—literally turning one turbine—you can get 50 percent, which is extremely high. Typical simple cycles turbines are around 25-30 percent efficient.

Ultimately, any solar, wind, or battery technology, anything that uses a rare earth metal, is going to have an environmental impact because of the initial mining operation. This is often not figured into the greenness of a technology. If you're making solar PV cell and it uses scandium or

whatever, well that's great, but guess what, there's only about three places in the world where you can get it from, and the guys that are mining it are probably all going to die of cancer. Is it really that great? Green for us, not green for them. And the products only last about ten years. You see the same thing with windmills, you see the same thing with a lot of the battery-operated lithium technologies, it is highly toxic to process. I mean it's great because it gives us all thin computers and all that other jazz but it's mined somewhere, then it's processed and refined and you need power to do that.

IX. HAS THERE BEEN ANYTHING FROM A REGULATORY PERSPECTIVE THAT HAS KEPT YOU FROM MOVING YOUR GOALS FORWARD AS QUICKLY AS YOU WOULD HAVE LIKED? DO YOU HAVE ANY MAJOR REGULATORY CONCERNS AT THIS TIME?

From a regulatory perspective, because we're in this small size category, there are *some* hurdles, but nothing insurmountable. At five MWe, by law, the utilities *have* to buy it. Later on, down the road, we'll want to produce more. From five to twenty-five MWe, you're still avoiding a lot of the FERC [Federal Energy Regulatory Commission] mandates. Anything above, and they're involved. You can imagine states, say Nevada, where they use a tremendous amount of power. In Nevada, we could site four machines in one place, produce twenty MWe of power, and they would likely buy our power.

When I think about regulation, the things that concern me are the market distortion effects of well-intended but misplaced clean regulation. California experienced some of this with the Small Generation Incentive Program Municipal-based utilities, which are eligible for below-market rate bonds. This would allow them to advance power projects that meet renewable goals and tap into additional renewable energy subsidies and tax credits. The challenge here is that some of these projects would not be able to stand on their feet economically without subsidies.

Locally, I-937 created a renewable energy credit, proof that you generated a megawatt hour of renewable power. So you can apply for that using certain heat sources—seventeen utilities are required under I-937 to comply. But, again, hydro is not included in I-937, so they either have to go build the source or go out on the open market and buy the energy credit.

X. IS THERE A SIGNIFICANT AMOUNT OF INTELLECTUAL PROPERTY INVOLVED IN THE DEVELOPMENT OF THESE TECHNOLOGIES? IF SO, HOW WILL YOU PROTECT THIS IP AS YOU CONTINUE TO EXPAND?

IP will be what keeps us in business at the end of the day. We file first for IP in the U.S. Once that patent is issued, you have a window of time to do a PCT—Patent Cooperation Treaty—filing. This provides patent protection internationally for inventions. We're in the PTC filing window with about three patents right now and we'll have another jumping in. Finding translation services, especially legal translation services for which there is an engineering component is also really, really challenging.

XI. IT LOOKS LIKE SOME OF YOUR FUNDING WILL COME FROM SUBSIDIES, AT LEAST FOR A WHILE. AS YOU BEGIN TO EXPORT, DO YOU ANTICIPATE ANY PUSHBACK FROM INTERNATIONAL COMMUNITY RELATING TO THESE SUBSIDIES?

Though we're not trying to build a business that's based off subsidies, we could apply for some funding through I-937 as a compliant site. We will eventually expand internationally to fill energy needs in certain markets – for example, in Germany, the big industrial size companies are all generating their own power because the power rates in Germany are ridiculous. Hooked up to a grid, they wouldn't be able to operate something like an aluminum foundry, which requires a ton of electricity. But as we expand to certain markets, especially to China, India, and the other developing economies, the issue that arises isn't so much their concerns about subsidies under World Trade Organization rules–which address subsidies as well as other trade-distorting measures–as the requirement for some kind of joint venture. For example, a Chinese corporation must own a minimum of 51 percent in the required joint venture, and then the real challenge is how to protect your IP in that market.

When it comes down to power, power is a commodity, but there's no worldwide price. There's not even a statewide price. This is partially why all the cloud computing is here in Eastern Washington, because comparatively, power is practically free here. Cloud computing can basically hook itself up to a hydro dam, and take off. All the same, I could see how subsidies considerations could be a larger issue in the future.