Mark Jacobson: How One American Atmospheric and Climate Scientist Created Clean Energy Roadmaps for 50 U.S. States--and 139 Nations

By John J. Berger, *Sustain Europe* U.S. Correspondent

Through a series of breakthrough climate and energy computer models, atmospheric scientist and modeller Mark Z. Jacobson has shown how the world can go to 100 percent clean, renewable energy without the need for nuclear power, coal carbon capture, or combustion biofuels. *Sustain Europe's* U.S. Correspondent John J. Berger met extensively with Professor Jacobson to learn about his extraordinary career and his views on how to address the climate crisis. Following the overview of Jacobson's work and impact, we present excerpts from Dr. Berger's interviews in a Question and Answer format.

GREAT RESEARCH ACHIEVEMENTS don't always arise from altruistic impulses. Some scientists are just driven by intense curiosity to figure out how the world works. But for Stanford climate and energy scientist Mark Z. Jacobson—a clean energy champion—the impetus for his remarkably productive research career was indeed altruistic.

Early in life, Jacobson noticed he was good at science and math—and tennis. Serendipitously, the tennis matches he played competitively as a teenager on "bad air days" in Los Angeles first got him interested in air pollution. He wondered with the innocence of youth whether he could use his quantitative skills to fix it.

That question eventually led to a Ph.D. in atmospheric science from UCLA and to international renown as an atmospheric modeller and renewable energy researcher. Jacobson also became known for important discoveries in climate science and for building powerful climate models.

He is one of those lucky, gifted people for whom solving difficult, challenging problems that stymie others is genuinely fun.

Mastering the game of tennis, however, taught him more than how to slice a serve or place the ball out of his opponent's reach. By his own account, tennis taught him the self-discipline and time management skills that ultimately proved crucial to his scientific and academic success.

Right after graduating from Stanford, he even played professionally for a while, until sidelined by a bone chip in the knee and a botched surgery to repair it. During the ten years it took him to fully recover, he went to graduate school and began the work that was to make his reputation.

Despite the successful scientific and academic career that followed, the tall, athletic Jacobson, now 53, is soft-spoken and unpretentious, even a trifle boyish. While his work ethic is palpable, he nonetheless appears relaxed and confident.

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approaches building and coding his complex air pollution, energy, and climate models with the passion of a teenager hooked on an addictive new video game.

That modelling and related meticulous research has led him to the conviction that all we need to free ourselves from fossil fuels and overcome the climate crisis are wind, water, and solar energy resources.

Avoided Costs

Adopting 100 percent clean, renewable energy, he contends, saves money, energy, and creates jobs, while reducing the health and environmental impacts of fossil fuels. We could, he maintains, also avoid 4 million deaths from air pollution each year, along with trillions in global warming costs.

His work has convincingly demonstrated that it is not only technically and economically feasible but economically beneficial for 139 countries to meet all of their energy needs using only power from clean, renewable resources.

The energy roadmaps he has created for those countries show that a rapid energy transition to 100 percent clean, renewable energy would create more than 24 million net new jobs by 2050. The fuel-free, fully electrified economy would also reduce energy costs and cut projected power demands by more than 42 percent.

Jacobson has also shaken up atmospheric and climate science. Using sophisticated, original computer models, he has discovered that black carbon in soot, and not methane as previously believed, is actually the world's second most powerful cause of global warming.

Setting the Record Straight

Producers of corn ethanol, a biofuel, are now on the defensive as Jacobson has proven that—far from reducing air pollution in cities like LA—ethanol actually makes air pollution worse. His research has also shown that, contrary to previous belief, biomass burning also contributes to warming. The dark particles trap radiant energy.

Professor Jacobson's energy roadmaps for each state in the U.S. have given political leaders and policymakers confidence that setting ambitious de-carbonization goals will neither cause blackouts and brownouts nor create energy price burdens nor economic shocks.

For example, after meetings with Jacobson and his associates, Governor Andrew Cuomo, Jr. of New York proposed that the state get 100 percent of its electricity from carbon-free renewable sources by 2040—the most ambitious clean power goal in the nation. The governor also proposed that the state develop 9,000 megawatts of offshore wind power by 2035.

Today not only New York State but California, Washington, Colorado, Hawaii, New Jersey, New Mexico, and the District of Columbia all have adopted various ambitious schedules for achieving 100 percent clean, renewable power, and some, more broadly, for renewable energy.

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Jacobson also provided his findings to former California Governor Jerry Brown. Before leaving office, Brown signed an Executive Order calling for the state to attain carbon neutrality by 2045 and to become net carbon negative every year thereafter.

Despite the criticism he has encountered from some who differ with his conclusions and have tried to discredit his research, Jacobson has prevailed over most critics as he once triumphed over opponents on the tennis court.

Unlike some politicians and academics who promote nuclear power and technologies to extend the use of fossil fuels, Jacobson does not subscribe to an "all of the above" menu of energy choices.

Dispelling Myths About Renewables

We can leave fossil fuels behind and move to 100 percent clean, renewable energy, according to Jacobson, without any nuclear power, coal carbon capture, or biofuel combustion. Some prominent academics committed to those technologies have been his most aggressive critics.

For decades, of course, the fossil fuel and nuclear power industries persistently disparaged renewable energy. Like metallic chaff ejected from an aircraft to confuse an incoming missile, defenders of conventional, status quo energy systems have put out objection after objection to clean energy.

Renewable energy was too diffuse, too intermittent and hence too unreliable. It was too costly. It would occupy too much land. It would take more energy to build than it would render. Raw materials shortages would stifle its growth and prevent scale-up to truly meet our energy needs.

Arguably Jacobson, with the help of his powerful computer models, has done more than any other scientist to concisely and convincingly prove these myths to be false. He has shown that the U.S. electric grid can be reliable with 100 percent of the energy coming from wind, water, and solar—and he received the Cozzarelli Prize for his research from the Proceedings of the National Academy of Sciences. It's an award given to only six out of 16,000 papers each year.

Sustain Europe recently spoke at length with Professor Jacobson about his life and his research as well as the controversy his research has provoked. We wanted to learn what motivated him to make atmospheric science, climate, and energy studies his life work. We also wanted to gain more insight into how he has been able to cause governors and other important political leaders to advance their renewable energy timetables. We met Dr. Jacobson at his net-energy-positive solar home in Palo Alto, CA, near the Stanford University campus. Our conversations have been edited and excerpted.

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Interview with Stanford University Clean Energy Champion Mark Z. Jacobson

John J. Berger (JJB): How did you decide to focus on energy and climate problems?

Mark Z. Jacobson (MZJ): I've been interested in understanding and solving air pollution and climate problems since I was 15 or 16 years old. At the time it was more about air pollution. I used to travel to Los Angeles and San Diego in the 1970s to play tennis, and it was extremely polluted, so it was just very miserable to breathe in this air. I just thought, why should people live like this? This should be a solvable problem. Later I also empathized with people and was thinking, why should anybody die of asthma or cardiovascular disease [from air pollution]. My experience with tennis made me realize that trying to solve this problem was a good goal.

JJB: What did you learn from tennis?

MZJ: I learned a lot of things from tennis that I took with me to academics. In tennis, everybody loses, so nobody likes when people brag. I learned to be humble, and not to fly off the handle [when you lose]. I do things more measuredly. I realized you just have to be stoic . . . There's this Rudyard Kipling poem called *"If."*

"If you can keep your head when all about you are losing theirs and blaming it on you, if you can trust yourself when all men doubt you, but make allowances for their doubting, too. . . ." [At the time] I was also playing tennis and studying to get degrees. So I also learned how to manage my time really well. That is the reason I've been really productive ever since, because, starting in high school, I just learned how to be very efficient at studying and working and concentrating, then shifting gears to play tennis.

JJB: How do we go from your interest in air pollution and your sense of agency and ability to tackle a major problem like that, to focusing on climate and energy and having the confidence to do the work that you're doing now?

MZJ: I wanted to study pollution or climate or both to understand the problems. I was good at math and science and engineering, so I figured, okay, might as well do what I'm good at, and then try to apply it to what I'm interested in. My first goal was to understand the problems better, technically. I was looking for a place to study, and I went down to UCLA. There, I met a professor who needed a student. He had a great topic, which was to build a computer model to study Los Angeles air pollution. So, I started a PhD there.

I was really thrown into this new research area where I had to learn from scratch how to decipher other people's computer programs and build my own. There was a period of about four months where I was just struggling with this massive computer program. It was really daunting and frustrating, but at some point, something snapped in me, and I figured it out. And I thought, now I understand this, and it really got me excited. I became almost addicted, first to understanding these programs, then starting to write my own. My overall goal became to build an air pollution model for Los Angeles, which would be literally only the third air pollution model in the world.

Because the goal was to understand air pollution, I started with one computer code that did chemistry. It was very accurate, but it was impractical. You couldn't apply it in a three-dimensional model because it took so much computer time just to give you one value for one location, let alone for tens of thousands or millions of grid points that you needed values for in a three-dimensional model.

My first goal was to try to build a code that does the same thing, but is much faster and that you can actually use in a three-dimensional atmospheric model, a climate model . . . . I figured out a way to speed it up by a factor of 2,000 without changing the accuracy at all. [It] really opened up the door for studying atmospheric chemistry on a global scale, because before, all the estimates for chemistry had to be really simplified, because you just couldn't solve hundreds to thousands of equations accurately in every nodule in a three-dimensional model.

I have a goal to get people out of poverty, to make their lives better, to reduce the number of deaths that are and going to be caused either by air pollution or climate change.

So, I came up with a technique to solve the chemistry really accurately and really quickly in a global and regional model.

JJB: Was that your Ph. D.?

MZJ: No, that was just the first year. I had a bigger ambition. I said, okay, that's one thing, but I really want to build a model to study air pollution, because, I mean, chemistry is one thing, one part of air pollution, but besides emissions, there's also meteorology. Then there are aerosol processes. The chemistry is mostly for gases, but there are also particles in the air, and they evolve from gases, and then there are a lot of physical processes that affect the particles, and there are particles that have different size and composition. You have to model those, too, to study air pollution, and you have to model radiative transfer, which is radiation coming through the atmosphere, solar and infrared, and there are surface processes. So, actually, studying air pollution is much more involved than just the gas chemistry, but I did the gas chemistry, and that kind of served as the core for everything else. . . .

So for my PhD, I ended up building an entire air pollution model focusing mostly on the aerosol processes, in addition to the gas processes, and also integrating another student's meteorology and another scientist's radiation transfer. So I built the first model in the world to interactively treat weather, radiation, gases, and particles, and surface processes all together, with feedback among all processes.

JJB: What is it like to build a computer model? How much effort does it take, how difficult it is, and is it typical for teams to build them and unusual for one person to do it?

MZJ: It's totally unusual. First of all, I don't even think of it as a job. It's totally fun, because I just loved it. I couldn't wait to get to it. I mean, I was addicted to it, because, you're doing something just so far beyond what anybody else has done. And you have this power to apply it anywhere in the world at any resolution, and it's also nested, so I can focus, I can treat the global scale, then focus down to the regional scale. It's just addictive, kind of like the tennis was addictive, to just improve it. It did take, well, I've been working on it since 1990, and it's 2019 right now, so, that's 29 years I've been working on this model.

JJB: How did your interest in atmospheric science lead to your interest in climate change, and then into clean energy?

MZJ: For my PhD, I tackled the air pollution problem, but I also wanted to be able to look at climate along with air pollution. So I built a global climate model after I built the urban air pollution model. Then I thought to myself, well, why not link them together?

JJB: How did you get interested in climate sufficiently to want to build a climate model?

MZJ: It even goes back to when I was still a teenager. I wanted to solve the air pollution problem, but I was also aware of other problems, such as acid deposition and climate change. I think in the late 1970s there was even an article about global climate change that influenced me.

JJB: Your interest in climate was sparked by the journalistic coverage?

MZJ: Later, I took one particular class at Stanford where we had to do essays and I wrote on acid deposition and maybe I also did a climate topic. . . . In terms of the climate issue, it was sitting at the back of my mind the whole time, but I figured I had to do the air pollution model first, because you have to start somewhere.

I also thought, I'm going to do something different from what other people have done, because there were other climate models around at the time, but they were not built as air pollution models. They didn't have the details of the chemistry or the aerosols, so you couldn't do the clouds right. They had all these simplifications for clouds and particles and radiation as a result. I thought, I'm just going to build a thing as complex as possible, and then I'm going to make that into a global [climate] model, because nobody had [built a model like that] before.

JJB: Why did the climate issue call to you so powerfully that you felt you wanted to commit to solving climate problems?

MZJ: The goal of my whole career is to try to understand and solve problems. I don't care so much about the intellectual curiosity of it, I care really about solving the problem, about really keeping my eye on the ball—that's another thing I learned from tennis. So, I felt I have the ability to take a lot of people out of poverty, if I can actually get this. I don't actually have the personal ability, but I have a goal to get people out of poverty, to make their lives better, to reduce the number of deaths that are and going to be caused either by air pollution or climate change.

JJB: Have you participated in the Intergovernmental Panel on Climate Change (IPCC) process as an author, or an editor, or a consultant?

MZJ: A lot of my papers are cited in IPCC reports, and I've also been a reviewer.

JJB: Are there any other landmark discoveries that you would like to mention?

MZJ: Another one that I thought was kind of cool was that pollution particles actually decrease wind speeds at the surface. Layers of pollution slow down the winds at the Earth's surface.

JJB: You came up with a finding that ethanol was actually worse than gasoline. Is that because of the subsidiary emissions that take place in growing, harvesting, transporting, and processing, or is it simply because of the air pollution impacts of ethanol versus gasoline at the tailpipe?

MZJ: If you just look at the tailpipe emissions, the impacts depend on what other air pollutants are present in the air where the emissions occur. Given those known background pollutants, ethanol causes more ozone than gasoline in 80 percent of American cities. But it's the other way around in the remaining 20 percent. Let's say the health impacts between gasoline and ethanol differ by two percent. But, you know, electric cars will eliminate 100 percent of the 20,000 deaths caused each year by gasoline and diesel vehicle tailpipe air pollution. So the point is that ethanol's not good for you in any way. It has been pushed by agriculture people who want a new market for their crops. They claimed it was a climate benefit, and then they started claiming there was an air pollution benefit, which are both incorrect.

Below and opposite page:
Professor Jacobson's energy-efficient net energy positive solar home in Palo Alto, CA

Right:
Electric vehicles and Tesla Powerwall energy storage units in Professor Jacobson's garage

You can't pipeline ethanol around. You have to diesel-truck, train, or barge it around. In Brazil they actually burn the sugarcane fields because that's how you get the sugarcane out. So, you have this black, forest-fire-type smoke, and they're claiming that's reducing air pollution?

JJB: It's amazing that there are such widespread misconceptions about ethanol and about biofuels.

MZJ: The reason the models I developed have been such useful tools is because I could actually dispel these myths, or at least understand them. In some cases, people were telling me hydrogen would be really bad, but you can actually model it and say, no, actually hydrogen won't be bad for the environment.

JJB: How fast could a clean energy transition actually be done? Are you optimistic or pessimistic at this point, knowing how critical it is that we have a very quick reduction in greenhouse gases?

MZJ: I'm optimistic that we can solve the problem, because I find that numerically, on paper, we can. Prices have also come down so much for what we need. That makes me optimistic, too. Now, we also have some political willpower. Today, in fact, New York proposed a hundred percent renewables.

JJB: How do we get from knowing that it's technologically possible to actually getting it implemented fast enough?

MZJ: I actually got a call from Bernie Sanders before the presidential election in 2016. He said, "I want to bring forward your hundred-percent renewable plans for the 50 states to the Senate. Since then, he has actually cosponsored legislation to that effect—Senate Bill 987. Other bills and resolutions have also been introduced in the House and Senate setting goals for clean, renewable electricity and/or all energy.

JJB: In California we're committed to clean energy as well as clean electricity.

MZJ: There's a clean, renewable electricity law with a 2045 goal. Separately, Governor Brown signed a non-binding executive order on clean, renewable energy. But all new homes have to have solar panels on their rooftops starting in 2020. Also, the California Air Resources Board has a mandate to be able to reduce transportation emissions to zero. CARB actually has the ability to ratchet down the emission standards, so that effectively all you can buy is an electric car. But we do need more legislation, like in industry, and maybe something more specific in transportation, and to retrofit existing buildings.

JJB: If we rely on 50 states to pass legislation without some type of federal legislation to coordinate the whole effort, we might not get to where we really want to go. Especially if we have to rely on individual regions and cities, then the whole effort becomes a bit fragmented. How do we get a coherent national, and ultimately a coherent international effort that, let's say, sets carbon quotas for different nations, and then has some sort of enforcement power to see that a realistic plan with some teeth gets implemented?

MZJ: I think you need these plans, rules, and laws at all levels. Having a federal law would help, but I think we should also have state laws. The more laws, the better. A federal law is not going to happen with the current administration, but we need federal laws to try to speed up this transition.

Fortunately, the costs have come down so much that transitions are going on without laws. Iowa is 43-45 percent wind now, and has no laws for wind. You don't always need laws to actually go to renewable energy, you mainly need low costs. Nine of the top ten wind states in the U.S. are all Republican states without many laws favouring wind. You don't need to convince people when they're making money off something. It doesn't have to be a political issue.

But you're right, if you want to get the thing sped up in all sectors, you do need enforcement of laws, and you have to push on all levels of government.

JJB: What are some other steps that help turn energy roadmaps into reality?

MZJ: Education. Getting information out to more people about what's possible, what the benefits are. This house is all-electric—there's no gas. It actually produces, in the annual average, 20 percent more electricity than it consumes. I've got two electric cars. My son has a third electric car that I charge. So, last year I paid no gas bill, no gasoline bill and no electric bill, and I was paid 530 dollars by my utility for the extra electricity.

I did a calculation of the payback time. With the subsidies that exist, it's five to six years, at the most. Without the subsidy, it would be nine to ten years.

JJB: How large is this house?

MZJ: 3,000 square feet, but it has heat pumps that use one-fourth the energy as a gas heater or electric resistance heater. The water heater's also a heat pump. It uses a quarter of the energy of a gas water heater. All the lights are LEDs, and the house is super-insulated. There is an induction cook-top stove. It boils water in half the time as gas. All these new technologies hardly use any energy. If people changed their homes, or when they're building a new home did something similar, I mean, I saved $6,000 just by not hooking up gas to the property. That's how much PG&E would charge me for a gas hook-up fee. And I saved another 5 or $6,000 on pipes. I didn't need any gas pipes.

Let's say the health impacts between gasoline and ethanol differ by two percent. But, you know, electric cars will eliminate 100 percent of the 20,000 deaths caused each year by gasoline and diesel vehicle tailpipe air pollution.

JJB: Any other interesting technologies or features in the house?

MZJ: The windows are triple-paned, and there are batteries in the garage. Batteries are cheap now. And the house is framed in prefabricated steel that's 80 percent recycled, instead of wood. They deliver it on a truck and assemble it like Legos. It's more precise so there are fewer errors when building the house, and its stronger and more secure from an earthquake point of view. There's also no wood waste on the property.

JJB: I know we've touched on this before, but broadly speaking, how feasible it is politically, legally, financially, and administratively to actually implement the clean energy pathway work that you've done?

MZJ: In the U.S. there's already a transition going on in several places. Several states have 100 percent renewable power mandates. Hawaii and California are committed to 100 percent renewable electricity by 2045. Other states are lined up behind them. New York's governor has committed to it and I think there'll be a vote on that.

For energy aside from electricity, there's less progress. We need legislation to address transportation, buildings, heat, and industrial heat. But there is no technical or economic barrier to actually doing this. I actually think the low-hanging fruit is in buildings and transportation. It's even easier I think than in the electricity sector.

JJB: To be devil's advocate, you addressed the technical feasibility question, but I'm interested in how we overcome the real world political obstacles, the public policy obstacles, and the financial obstacles because many people who might do this if they had financing on favourable terms might not have easy access to financing.

MZJ: It's a combination of the low cost of the technologies and policies to be put in place. The way to get it in countries that have elections and accountable policymakers is to vote in policymakers who will do this for us.

We have lots of activists on the ground right now and nonprofits who are going state by state, community by community and helping those communities that are close to wanting to do this, implement laws in those communities.

JJB: Is that why you started the Solutions Project and the 100.org Project? [Editor's note: The Solutions Project is devoted to advancing the cause of 100 percent clean, renewable energy for all. 100.org supports racial and gender equality in the transition to clean, renewable energy.]

MZJ: No, we started the Solutions Project in July 2011. I was invited to a meeting with [actor] Mark Ruffalo, and [film producer] Josh Fox, organized by [businessman] Marco Krapels. Mark Ruffalo and Josh Fox were activists in the entertainment industry and Marco Krapels knew that I had been working on an energy plan to transition the world to renewable energy. The meeting was mostly to bring me together with people from New York to talk about what we could do in New York as an alternative to fracking.

I said there's a lot of clean, renewable energy as an alternative. They then wanted me to build a plan for New York. I said I don't have time, but I will write a paragraph. Then maybe you can hire a consulting company to write a plan starting with that paragraph. They agreed. One night I started writing the paragraph but I got inspired and so the next morning I turned up and sent them a 14-page, single-spaced manuscript. I actually took our global plan and squished it down into a plan for New York and found some additional data. So overnight I developed a conceptual outline for a New York State Energy plan.

JJB: What was their reaction when you turned up with this 14-page document the next morning?

MZJ: Shock and awe. I surprised myself.

Once we had this white paper in 2011, we started chatting on the phone a lot and really became very close friends. We decided that we had something and should take it to the governor. So Mark Ruffalo and Josh Fox had all these contacts with policymakers and other celebrities in New York and also with nonprofits. So after giving some talks and drawing lots of people in, including other celebrities, we formed the Solutions Project as an informal group—it wasn't a nonprofit until 2013.

People were protesting against fracking everywhere at this time in New York State. I'd never been to a rally before but went to a rally in Albany in front of the governor's office. I spoke to a crowd of three thousand people with signs, chanting, and marching. Through the scientific energy plan for New York and the public support for it, we eventually got the ear of the governor.

So who does the Trump administration hire to be their expert witnesses but three authors on the paper critical of my work. These are people who are fighting against climate action.

JJB: Andrew Cuomo, Jr.

MZJ: He was kind of on the fence about fracking. I felt he wanted to ban it but didn't want to make a rash decision. Ultimately he did ask us to provide five first steps to transition, and he ended up adopting three of them. He finally banned fracking largely due to all this activism and the actual health and environmental concerns about fracking, but also because there was this alternative plan that we had presented to the governor's office.

JJB: What steps did he adopt?

MZJ: Installing lots of charging stations, a green bank, a solar rooftop policy, and then subsequently offshore wind. Since then, he actually enacted a law for 50 percent renewable electricity by 2030, and now he's proposed 100 percent by 2040 for electricity, and I think also for some other sectors, too. He's been pushing in that direction. There is also a competing proposed law in the state Senate for 100 percent renewables by 2030. I think our plans helped.

In the middle of doing the New York stuff, I thought, why not just do the same thing for California? So I started working on a California energy plan with students at Stanford and with researcher Mark Delucchi [of UC Berkeley's Institute of Transportation Studies], and we ended up going to the governor's office in California as well. Two months later, Brown proposed a 50 percent renewable electricity law. It was pretty clear from all our communications that it had given them confidence to be able to do something like that.

JJB: So you answered the question about the technical feasibility and the economic feasibility for them.

MZJ: Answered that and then all these others. By that time, we had the Solutions Project as a real nonprofit. {It was structured around Jacobson's well-researched scientific plans.] In addition to the plans, we had this celebrity group. Not only Mark Ruffalo and Josh Fox but all the people they brought along. Leo DiCaprio joined us and spoke to the United Nations and at the Oscars.

When I came back to California [from New York State] I developed a plan to send to Governor Brown's office. I engaged with some people at the Sierra Club as well. They ran with the idea of going to cities and trying to convert them to 100 percent renewables. They've been really successful with that, converting now I think 110 cities and counties around the U.S.

JJB: When you say converting, what we're really talking about is adopting plans to convert?

MZJ: Agreeing to either commitments or city resolutions or council resolutions. They ended up voting on them and passing them. Now there are over 100 nonprofits that are supporting this whole 100 percent movement. They have been really instrumental in engaging the public and talking to policymakers. Now we have all these policymakers [including] the seven new governors who have committed to 100 percent renewable energy in addition to California and New York. There are Michigan, Colorado, Connecticut, Nevada, Wisconsin, Illinois, and Maine.

As a result of all the organizing, [Senator] Bernie Sanders adopted our plans as part of his presidential platform in 2016 and put our maps on his website. He committed to 100 percent. [Maryland Governor] O'Malley actually committed to 100 percent first. . . . Hillary Clinton said we have to go as quickly as possible to 100 percent renewable energy and nothing should get in our way. Then the Democratic National Committee adopted 100 percent as part of the platform. We were small but pretty effective.

JJB: Once you have a template plan for one state, then you input the relevant data for the other state into your template? It's not really like you have to create 50 de novo plans.

MZJ: We ended up doing individual plans for New York, California, and Washington State, but then I automated it to do all 50 states simultaneously.

JJB: What are the lessons to be drawn from your state-level successes about how to get swift implementation of 100 percent clean energy in the United States?

MZJ: You have to go around to go to states, cities, towns, and individuals. That has been very effective. We got a good portion of the population now transitioning. Plus, in the Republican states, there is a transition going on as well, because wind and solar are so cheap.

JJB: What have been the challenges and difficulties that you personally encountered in doing your research?

MZJ: I've been really lucky that I found something that was new and that I could actually focus on and solve and was really passionate about. I've been really happy with my research results.

JJB: So the biggest barriers have been the people trying to bring you down?

MZJ: After we did our 50-state plan, we did a prize-winning follow-up grid stability study. Whereas previous grid-stability studies required computationally incredibly intensive calculations that took months of computer time, our model was built so that it could account for many more processes yet could run in four minutes.

JJB: This was for California?

MZJ: The first thing I did was for 48 contiguous U.S. states all together. That was the Proceedings of the National Academy of Sciences paper. Eventually I did it for all world regions.

For this we were subjected to attacks from people who went into this whole thing saying we're going to publicly bring this guy down. I'm involved in this case, the Children's Trust Case, which is Julianna versus the Federal Government. It's a bunch of children suing the government over climate change. They want the government to implement solutions, basically our solutions, because I'm one of the expert witnesses on behalf of the Children's Trust. So

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who does the Trump administration hire to be their expert witnesses but three authors on the paper critical of my work. These are people who are fighting against climate action, because this is exactly what the Juliana case is about.

JJB: Did you have the impression that the prominence of your research put a shadow over their research and made them less fundable by grantors?

MZJ: That's part of it, but it's more ideological. For example, one of them was promoting nuclear power. At the 2016 Paris conference he and three other prominent climate scientists had a press conference where they were saying the world should go to nuclear energy. They were promoting a 100 percent building out of nuclear energy. Another author on their paper had been an advisor at the Breakthrough Institute, which is an old nuclear think tank. Then there were some people doing carbon capture and sequestration, which we didn't think was necessary. All of them had some tie into this "all of the above," energy strategy which includes nuclear, coal with carbon capture, and biofuel.

At least three coauthors were economic policy people. They're all invested more in the conventional fossil fuel and "all of the above" policies and carbon capture. Another one from Stanford does a lot of work on natural gas. A lot of them were for everything, and we were just for clean, renewable energy.

JJB: What happened after that?

MZJ: Just to give you an idea of how secretive and unscientific this whole thing was, when somebody writes a commentary on your paper, usually they will ask for the data from your paper or the model to generate the data. It even said in our paper that data are available. Other people had asked for it and the model. These people decided to write a criticism claiming we made two major model errors in the paper without ever even asking for the model or the data output. The two major errors claimed were just based on their own mistakes. In one case, it wasn't even a mistake. It was intentional misinformation.

You can't write a paper saying somebody has a model error without actually looking at the model and the actual output to see if there is an error in there. They never did that, but in retrospect it's obvious because they didn't want to telegraph to me that they were writing this paper. They just wanted to publish it and then immediately issue press releases, which is what they did, and then leak all the stuff to advocates to write scathing articles about our work. That's exactly what happened.

This whole thing was an intentional hit job on their part to not follow the protocol for scientifically reviewing other people's work.

The journal sent me a copy of their paper before they published it. It's complete nonsense. Everything in it is just a lot of lies about our work. But they published this whole paper with reams of incorrect information, and we're supposed to correct every detail in a letter of a few hundred words. I told the journal that these people have made demonstrably false statements. I asked them to investigate this and decide whether to retract their paper, but the journal refused, even though the Proceedings of the National Academy of Sciences is a member of the Council of Publication Ethics. Ultimately, I published a new paper that addressed all the scientific issues. I was thus able to get enough information out to the public to show they had printed recklessly false facts and data about our paper.

JJB: What are you working on now?

MZJ: I'm writing a book for this new class I have to teach. Both the class and book are called 100 Percent, Clean, Renewable Energy and Storage for Everything. I'm also doing modelling of world energy resources and the impacts of implementing clean, renewable energy roadmaps on global climate. I also recently did a study of the impact of the massive 2015 Aliso Canyon gas leak on health and climate in California and in the Los Angeles area.

I actually got a call from Bernie Sanders before the presidential election in 2016. He said, "I want to bring forward your hundred-percent renewable plans for the 50 states to the Senate. Since then, he has actually cosponsored legislation to that effect—Senate Bill 987.

John J. Berger, PhD. (www.johnjberger.com) is an energy and environmental policy specialist who has produced ten books on climate, energy, and natural resource topics. He is the author of Climate Peril: The Intelligent Reader's Guide to the Climate Crisis, and Climate Myths: The Campaign Against Climate Science, and is at work on a new book about climate solutions.

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