

ADVANCING THE NEXT GENERATION OF SOLAR AND WIND ENERGY TECHNOLOGIES

HEARING BEFORE THE SUBCOMMITTEE ON ENERGY COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY HOUSE OF REPRESENTATIVES ONE HUNDRED SIXTEENTH CONGRESS

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ADVANCING THE NEXT GENERATION OF SOLAR AND WIND ENERGY TECHNOLOGIES

WEDNESDAY, MAY 15, 2019

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to notice, at 10:04 a.m., in room 2318 of the Rayburn House Office Building, Hon. Conor Lamb [Chairman of the Subcommittee] presiding.

**COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY
U.S. HOUSE OF REPRESENTATIVES
HEARING CHARTER**

Advancing the Next Generation of Solar and Wind Energy Technologies

Wednesday, May 15, 2019

10:00AM EST

2318 Rayburn House Office Building, Washington, D.C. 20015

PURPOSE

The purpose of the hearing is to examine the range of research, development, and demonstration (RD&D) activities required to advance solar and wind energy technologies. Specifically, the hearing will serve to inform the development of legislation that will guide the Department of Energy's (DOE) activities in these areas. Many solar and wind energy technologies are now widespread and growing, but further innovation is needed to ultimately deploy these technologies at a greater scale that can be a major factor in reducing the impacts of climate change. The discussion will focus on the value of existing federal solar and wind energy research, development, and demonstration activities, and the next steps that these programs should be pursuing.

WITNESSES

- **Dr. Peter Green** is Science and Technology Officer and Deputy Laboratory Director for the National Renewable Energy Laboratory (NREL). He is responsible for developing NREL's research goals and strengthening its core capabilities, including the Laboratory's solar and wind energy technology activities. Before his current position, he was the Director of DOE's Energy Frontier Research Center for solar and thermal energy conversion and a scientist at Sandia National Laboratory researching polymers, glass, and electronic ceramics.
- **Ms. Abby Hopper, Esq.** is President and CEO of the Solar Energy Industries Association (SEIA). Before leading SEIA, she was Director for the Department of Interior's Bureau of Ocean Energy Management and, previous to that, Director of the Maryland Energy Administration.
- **Mr. Kenny Stein, Esq.** is Director of Policy at the Institute for Energy Research. He has previously held several positions for Senator Ted Cruz, including Legislative Counsel,

covering energy, environment, and agriculture issues, and served as Policy Advisor for the Cruz Presidential Campaign.

- **Mr. Tom Kiernan** is President and CEO of the American Wind Energy Association (AWEA). Prior to joining AWEA, he was President of the National Parks Conservation Association for 15 years and served various roles in the Environmental Protection Agency's Office of Air and Radiation.

Solar and Wind Energy Technology

Significant advances in solar and wind energy technologies have occurred over the past 40 years. According to a 2018 Report by Lazard, the unsubsidized, levelized cost of energy for solar photovoltaic systems and wind power dropped 88% and 69% since 2009, respectively, making each generation source competitive, if not cheaper than fossil fuel generation in some scenarios.¹ These cost decreases have been primarily driven by improvements in solar photovoltaics and wind turbines. In addition to increased affordability, the efficiency, scale, and distribution of solar and wind energy technologies has improved.² Federal RD&D led by DOE has contributed to these industries and continues to advance solar and wind energy technologies.

Solar Energy Research, Development, and Demonstration

In 1977, DOE launched the Solar Energy Research Institute to explore ways to harness power from the sun. This institute and its successor, the National Renewable Energy Laboratory (NREL), demonstrated some of the first concentrated solar power projects in the world and developed photovoltaic cells with record-setting conversion efficiencies. In 1994, NREL developed a solar photovoltaic cell that became the first to exceed 30% efficiency^{3,4}. Over time, many of these technologies were matured and commercialized by the private sector. But according to several assessments produced by the Department of Energy, despite the growth of the solar industry over the past 20 years, continued technology advancements are needed to reach DOE's SunShot Initiative goal of solar energy meeting 14% of U.S. electricity needs by 2030 and 27% by 2050. If these goals are achieved, DOE estimates that by 2050, carbon dioxide emissions would be 28% lower than in a business-as-usual scenario and the solar industry could support 390,000 more jobs.⁵

¹ "Levelized Cost of Energy Analysis—Version 12.0." Lazard. <https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2018/>

² "2017 Renewable Energy Data book." National Renewable Energy Laboratory. <https://www.nrel.gov/docs/fy19osti/72170.pdf>

³ "The History of Solar." U.S. Department of Energy. https://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf

⁴ "Photovoltaics Research and Development." U.S. Department of Energy.

<https://www.energy.gov/eere/solar/photovoltaics-research-and-development>

⁵ "Sunshot Vision Study." U.S. Department of Energy. <https://www.energy.gov/eere/solar/sunshot-vision-study>

Wind Energy Research, Development, and Demonstration

Similarly, Federal RD&D began supporting wind energy technologies in the 1980s. In 1993, the National Wind Technology Center (NWTC), a facility meant to lead U.S. research in wind energy, was built at NREL. Since then, NWTC, DOE, and the Department of Interior launched an offshore wind energy initiative, building three offshore wind energy demonstration projects. Growing from this work, the University of Maine installed the first grid-connected offshore wind turbine in the U.S. with substantial DOE support.

Amidst these RD&D activities, the wind energy industry has grown tremendously. In 2018, there was enough wind energy in the U.S. to power 20 million homes.⁶ However, if wind energy is to meet the goal of supplying 35% of U.S. electricity by 2050, as outlined in the DOE Wind Vision report, continued research, development, and demonstration of these technologies and systems are needed.⁷ According to the report, this level of deployment would result in over 600,000 wind industry-supported jobs, billions of dollars in energy savings, and gigatons of air pollution avoided.⁸

Draft Solar and Wind Energy Research and Development Bills

The draft legislation that this hearing is meant to inform plans to guide DOE's work on wind and solar energy so that these technologies can achieve the ambitious goals laid out in DOE's Wind Vision and SunShot initiative, and more.

Draft Solar Energy Bill

The draft bill, currently titled the Solar Energy Research and Development Act of 2019, directs the Secretary of Energy to carry out a program for research, development, and demonstration of solar energy technologies. The program prioritizes solar energy technologies, including photovoltaic and concentrating solar power systems, that improve:

- a) capacity and efficiency;
- b) manufacturing, operation, and maintenance;
- c) reliability and security;
- d) grid integration; and
- e) affordability.

⁶ "History of U.S. Wind Energy." U.S. Department of Energy. <https://www.energy.gov/eere/wind/history-us-wind-energy>

⁷ "Wind Vision Detailed Roadmap Actions." U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2018/05/f51/WindVision-Update-052118-web_RMB.pdf

⁸ "Wind Vision." U.S. Department of Energy. <https://www.energy.gov/eere/wind/wind-vision>

The bill specifically directs the Secretary to conduct demonstration projects and pursue projects that improve U.S. domestic manufacturing, recycling, and environmental impact of solar energy technologies. It also authorizes 5% annual funding increases over 5 years for wind energy research, development, and demonstration activities, beginning with \$258.8 million in 2020, to carry out the Act.

Draft Wind Energy Bill

The draft bill, currently titled the Wind Energy Research and Development Act of 2019, is an update of bills previously introduced by Rep. Tonko in past Congresses, most recently H.R. 4423 in the 114th Congress. The current bill directs the Secretary of Energy to carry out a program for research, development, testing, and evaluation of wind energy technologies. The program prioritizes wind energy technologies, including both onshore and offshore turbines and airborne technologies, that improve:

- a) capacity and efficiency;
- b) manufacturing, construction, operation, and maintenance;
- c) reliability and security;
- d) operational capability in new geographic and atmospheric environments;
- e) grid integration; and
- f) affordability.

The bill also directs the Secretary to award grants for demonstration projects, including the establishment of a Hybrid Energy System Facility, currently proposed by the Administration⁹, that can demonstrate wind energy technologies in an electric grid system that incorporates diverse generation sources, loads, and storage technologies.

In addition, the bill directs the Secretary to support research technologies that reduce regulatory and market barriers, and support innovative wind energy technologies that are not present in DOE's RD&D portfolio or roadmaps. The Act authorizes 5% annual funding increases over 5 years for wind energy research, development, and demonstration activities, beginning with \$120 million in 2020, to carry out the Act.

⁹ "Department of Energy FY 2020 Congressional Budget Request, Volume 3 Part 2." Department of Energy. <https://www.energy.gov/sites/prod/files/2019/04/f61/doe-fy2020-budget-volume-3-Part-2.pdf>

Chairman LAMB. All right. This hearing will come to order. Without objection, the Chair is authorized to declare a recess at any time.

Good morning. Welcome to today's hearing, "Advancing the Next Generation of Solar and Wind Energy Technologies." I want to thank our panel of witnesses for being here today. We're waiting on one more who is on his way in. Very excited to hear your perspectives on the importance of Federal support for this crucial technology and what our next steps need to be.

Solar and wind energy, we all know, reduce air pollution, support thousands of American jobs, and can reduce energy costs to our constituents across the country, which is very important. The solar and wind industries have grown tremendously over the past 10 years, and the prices for their power have fallen. I have numbers here that show the price of wind energy having fallen 69 percent and the price of solar falling 88 percent. These technologies are now forms of energy that are in the mainstream providing cleaner air, creating a new green-collar sector, and lowering our utility bills. We believe that the solar and wind energy combined industries now employ over 350,000 Americans.

These industries, like many, are a success story when it comes to talking about Federal research and development. The Department of Energy established the Solar Energy Research Institute back in 1977, which later expanded and became NREL, the National Renewable Energy Laboratory. NREL set many of the early records for solar photovoltaic panels efficiency and they demonstrated some of the first concentrated solar power projects. They also house the National Wind Technology Center, and they've led offshore wind energy demonstration projects across the United States.

Despite these advances, we still need some serious technological leaps in order to grow at a significant scale. Even after all this work in 2018, solar and wind energy together combined to produce just 8.2 percent of our electricity in the U.S. It also appears that U.S. emissions increased from 2017 to 2018, and so we have some serious work to do.

I also think it's important to acknowledge that this discussion is not being had inside a vacuum or only within the boundaries of the United States. China understands very well the importance of developing and deploying these technologies. As of today, it's hard not to say that they are the clear leader in clean energy investment with over \$100 billion invested in this space in 2018 alone.

The United States was second, but we were \$35 billion behind China. We should close this gap. I believe that our money is better spent here and that we have the talent and technology and pipeline to do this. But this is going to be a market in the 21st century. There will be many more jobs at stake, there will be many more technologies at stake, and I want all those to be created here.

I'm looking forward then to using this hearing to learn a little bit more about the opportunities that are in front of us to make sure that we spend Federal research dollars productively and smartly to have the best results for our constituents.

Thank you again for appearing before me, and with that, I would like to recognize my colleague Mr. Weber for an opening statement.

[The prepared statement of Chairman Lamb follows:]

Good morning and thank you to our great panel of witnesses for being here today. I am excited to hear your valuable perspectives on the importance of federal support for solar and wind energy research, development, and demonstration activities and the next steps we need to be taking.

Solar and wind energy reduce air pollution, support thousands of American jobs, and can reduce energy costs to our constituents across the country. The solar and wind energy industries have grown tremendously over the past 10 years, and the prices for their power have fallen dramatically. In the last decade the price for wind energy fell 69%, and the price for solar fell 88%. These cost reductions have made wind and solar mainstream, resulting in cleaner air, a burgeoning green-collar sector, and lower utility bills. I am particularly excited to note that the solar and wind energy industries now employ over 350,000 Americans.

These industries, like many, have greatly benefited from federally funded R&D. It was the Department of Energy that established the Solar Energy Research Institute back in 1977, which later expanded and became the National Renewable Energy Laboratory, commonly known as NREL. NREL is responsible for setting many of the early records in solar photovoltaic panels' efficiencies and demonstrating some of the first concentrating solar power projects. NREL also houses the National Wind Technology Center, and in recent years, led cutting edge offshore wind energy demonstration projects in the U.S.

Despite the advances to solar and wind energy technologies, continued innovation in these technologies is needed to advance their growth at a significant scale. In 2018, solar and wind energy together combined to produce just 8.2% of our electricity in the U.S. (according to most recent data from EIA) and challenges remain to their widespread deployment. Moreover, studies suggest U.S. emissions increased from 2017 to 2018. This is an alarming reversal after three years of declining emissions and is concerning as we continue our efforts to reduce emissions and mitigate climate change.

I believe that net-zero emissions technologies such as solar and wind, and a broad array of other technologies, will play crucial roles in reducing greenhouse gas emissions from the electricity sector. Whether it's looking at new, more efficient materials for solar photovoltaic panels, or developing the next generation of floating, offshore wind turbines, next generation solar and wind energy technologies can and should play a key role in the transition to a clean energy economy.

That is why I look forward to using this hearing to further inform and refine the draft pieces of legislation that will guide DOE's solar and wind energy R&D activities. Each draft aims to provide stronger direction to the Department, reflecting significant changes to these technologies, their industries, and their future research needs. We need to ensure that we are doing everything we can to advance solar and wind energy technologies. With their potential for increased carbon-free electricity, American jobs, and lower electricity bills, we should work to reassert American leadership in this sector.

Thank you again for appearing before our committee and I'm looking forward to today's hearing.

Mr. WEBER. Thank you, Chairman Lamb, for holding today's Subcommittee hearing. I'm looking forward to hearing from our witnesses—Mr. Stein, we're glad you could join us—about the value of the state of solar and wind technologies in the U.S. and about DOE's (Department of Energy's) clean energy research, development, demonstration, and commercialization activities in these areas.

Solar and wind R&D is funded through the Department's Office of Energy Efficiency and Renewable Energy or EERE. After substantial growth during the Obama Administration, EERE is by far the largest applied research program. At almost \$2.4 billion in annual funding, EERE is bigger today than the funding provided for research in fossil energy, nuclear energy, electricity, and cybersecurity combined. The research programs for solar and wind also expanded during this unprecedented growth in spending. So I'm a little surprised to see my colleagues on the other side of the aisle propose legislation to grow these offices even more with an al-

most 60-percent increase in spending for wind R&D and almost 30-percent increase in solar R&D.

And I want to be clear. I'm very supportive of DOE funding for innovative research in new solar and new wind technologies. Most of you will know Texas is a leader in wind energy. I'm also supportive of the kind of basic research like advanced computing, machine learning, and advanced manufacturing and the development of new materials that benefits not just solar and wind but all forms of energy technologies. But we need to take a responsible and balanced approach to energy research and ensure that Federal investments go toward work that truly could not be accomplished by the private sector.

Let me add in the private sector, business is booming for wind and solar. Did I mention Texas is a leader in that? Last year, American renewable energy produced a record 742 million megawatt hours of electricity. Now, Mr. Chairman, you said that it was 8.2 percent. Our stats show 18 percent of the U.S. electricity generation. Maybe when you add those two, get 26, divide by 2, we got 13 percent of electricity generation, and doubled its production, by the way, from a decade ago. Great progress is being made. This significant increase is almost entirely due to the incorporation of additional wind and solar power.

Today, we're going to hear good news from our friends in these thriving industries that there are over 500 American factories building wind turbine parts, that a record 114,000 Americans have jobs supporting the wind industry and that there are currently 250,000 Americans working in the \$17 billion solar industry. It is abundantly clear that consumer demand is already driving increased deployment of these technologies. After all, this is what the industry is good at. But the private sector cannot conduct the fundamental research that lays the foundation for the next generation and the next technological breakthrough.

That means focusing our Federal programs on innovative technologies that are not already commercially deployed. For example, at the Center for Next Generation of Materials Design led by National Renewable Energy Laboratory, NREL, researchers work on advancing computational materials designed to discover new novel materials. By pursuing this breakthrough science in materials, we can fundamentally improve the performance of solar energy technologies.

With our national debt at over \$20 trillion and rising and mandatory spending caps guiding budgets on everything from energy to national defense, we simply cannot afford to increase the spending in every program. So we need to focus our efforts on truly groundbreaking research. Let us not duplicate the efforts of American industry. By prioritizing fundamental research with broad application to all forms of energy, we can enable the private sector to build innovative market, reduce energy costs, and grow the American technology.

And, Mr. Chairman, one more time, thank you. I'm going to yield back. I appreciate you doing this.

[The prepared statement of Mr. Weber follows:]

Thank you, Chairman Lamb, for holding today's subcommittee hearing. I'm looking forward to hearing from our witnesses about the value of the state of solar and

wind technologies in the U.S., and about DOE's clean energy research, development, demonstration and commercialization activities in these areas.

Solar and wind R&D is funded through the Department's Office of Energy Efficiency and Renewable Energy.

After substantial growth during the Obama Administration, EERE is by far the largest applied research program.

At almost \$2.4 billion in annual funding, EERE is bigger today than the funding provided for research in fossil energy, nuclear energy, electricity, and cybersecurity combined.

The research programs for solar and wind also expanded during this unprecedented growth in spending. So I'm surprised to see my colleagues on the other side of the aisle propose legislation to grow these offices even more - with an almost 60% increase in spending for wind R&D and almost 30% increase in solar R&D.

Now, I want to be clear - I'm supportive of DOE funding for innovative research in new solar and wind technologies.

I'm also supportive of the kind of basic research - like advanced computing, machine learning and advanced manufacturing, and the development of new materials - that benefits not just solar and wind, but all forms of energy technologies.

But we need to take a responsible and balanced approach to energy research and ensure that federal investments go towards work that truly could not be accomplished by the private sector. And in the private sector, business is booming for wind and solar.

Last year, American renewable energy produced a record 742 million megawatt hours of electricity.

This is almost 18 percent of the U.S. electricity generation and double its production from a decade ago. This significant increase is almost entirely due to the incorporation of additional wind and solar power.

Today, we'll hear good news from our friends in these thriving industries - that there are over 500 American factories building wind turbine parts, that a record 114,000 Americans have jobs supporting the wind industry, and that there currently 250,000 Americans working in the \$17 billion solar industry.

It is abundantly clear that consumer demand is already driving increased deployment of these technologies. This is what the industry is good at.

But the private sector can't conduct the fundamental research that lays the foundation for the next generation and the next technology breakthrough.

That means focusing federal programs on innovative technologies that aren't already commercially deployed.

For example, at the Center for Next Generation of Materials Design led by National Renewable Energy Laboratory (NREL), researchers work on advancing computational materials design to discover novel materials.

By pursuing this breakthrough science in materials, we can fundamentally improve the performance of solar energy technologies.

With our national debt at \$18 trillion and rising, and mandatory spending caps guiding budgets on everything from energy to national defense, we simply can't afford to increase spending for every program. So we need to focus our efforts on truly groundbreaking research - not on duplicating the efforts of American industry.

By prioritizing fundamental research with broad application to all forms of energy, we can enable the private sector to bring innovative new technology into the market, reduce energy costs, and grow the American economy.

Chairman LAMB. Thank you. And the Chair now recognizes Chairwoman Johnson for an opening statement.

Chairwoman JOHNSON. Thank you very much, Mr. Chairman, and thank you for having this timely hearing, the two most valuable renewable energy resources—solar energy and wind energy—are very important.

Over the past 10 years, costs of both wind and solar energy have decreased dramatically, making them a vital part of the energy mix of the United States. According to a recent report from Austin-based analysis firm TXP, solar and energy saved Texans \$5.7 billion in electricity costs from 2010 to 2017, compared to what they would have paid if these renewable energy sources were not part of the energy portfolio. And I might say the other energy is the highest in the Nation even though we are an oil-producing fossil fuel State.

I am proud to say that Texas now leads the United States in installed wind energy capacity, with over 24 gigawatts of wind energy. That's enough energy to power over 7 million homes. The wind energy industry also brings tens of thousands of jobs to the State, including jobs at several manufacturing facilities that support the wind industry by making products like blades, towers, and turbine housing that China is trying to take away from us.

All that being said, we still have significant investments we need to make to continue to innovate on these technologies, further bringing down their costs and making these technologies even more beneficial for Americans. In the wind industry, for example, we're exploring new technologies like offshore wind, which has significant potential for leveraging untapped energy resources near our coastal communities, and needs important R&D investments to help bring down costs. In the solar industry, we are continuing to explore new types of solar cells made of advanced materials with record-setting efficiencies, at affordable prices.

We really can make investments that are both good for the environment and for the economy. That's why I'm looking forward to hearing from the distinguished witnesses assembled here today to learn how we can support innovation in the solar and wind industries, ensuring that these important energy resources can play an even larger role in our clean energy future.

Thank you, and I yield back.

[The prepared statement of Chairwoman Johnson follows:]

Good morning and thank you, Chairman Lamb, for holding this timely hearing on two of our most valuable renewable energy resources, solar energy and wind energy.

Over the past ten years, costs of both wind and solar energy have decreased dramatically, making them a vital part of the energy mix of the U.S. According to a recent report from Austin-based analysis firm TXP, solar and wind energy saved Texans \$5.7 billion in electricity costs from 2010 to 2017, compared to what they would have paid if these renewable energy sources were not part of the energy portfolio.

I'm proud to say that Texas now leads the U.S. in installed wind energy capacity, with over 24 gigawatts of wind energy. That's enough energy to power over 7 million homes. The wind energy industry also brings tens of thousands of jobs to the state, including jobs at several manufacturing facilities that support the wind industry by making products like blades, towers, and turbine housings.

All that being said, we still have significant investments we need to make to continue to innovate on these technologies, further bringing down their costs and making these technologies even more beneficial for Americans. In the wind industry, for example, we are exploring new technologies like offshore wind, which has significant potential for leveraging untapped energy resources near our coastal communities, and needs important R&D investments to help bring down costs. In the solar industry, we are continuing to explore new types of solar cells made of advanced materials with record-setting efficiencies, at affordable prices.

We really can make investments that are both good for the environment, and for the economy. That's why I am looking forward to hearing from the distinguished witnesses assembled here today to learn about how we can support innovation in the solar and wind industries, ensuring that these important energy resources can play an even larger role in our clean energy future.

With that, I yield back.

Chairman LAMB. Thank you, Madam Chairwoman.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time I'd like to introduce our witnesses. First, Dr. Peter Green is Deputy Laboratory Director and Science and Technology

Officer for the National Renewable Energy Laboratory. He's responsible for developing NREL's research goals and strengthening its core capabilities, including the lab's solar and wind energy technology activities.

Before his current position, he was Director of DOE's Energy Frontier Research Center for solar and thermal energy conversion and a scientist at Sandia National Lab researching polymers, grass—glass, and electric ceramics.

Ms. Abby Hopper, Esquire, is President and CEO of the Solar Energy Industries Association. Before leading SEIA, she was Director for Department of Interior's Bureau of Ocean Energy Management, and previous to that, Director of the Maryland Energy Administration.

Mr. Kenny Stein, Esquire, is Director of Policy at the Institute for Energy Research. He's previously held positions for Senator Ted Cruz, including Legislative Counsel covering energy, environment, and ag issues and served as Policy Advisor for the Cruz Presidential campaign.

Finally, we have Mr. Tom Kiernan, who is President and CEO of the American Wind Energy Association. Prior to joining AWEA, he was the President of the National Parks Conservation Association for 15 years and served various roles at the EPA's Office of Air and Radiation.

As our witnesses should know, you will each have 5 minutes for your spoken testimony. Your written testimony will be included in its entirety in the record of the hearing. And when you have all finished speaking, we will begin with questions. Each Member will then have 5 minutes to question the panel. We will start with Dr. Green.

**TESTIMONY OF DR. PETER GREEN,
SCIENCE AND TECHNOLOGY OFFICER AND
DEPUTY LABORATORY DIRECTOR,
NATIONAL RENEWABLE ENERGY LABORATORY**

Dr. GREEN. Good morning. Chairman Johnson, Chairman Lamb, Ranking Member Weber, Ranking Member Lucas, I'd like to thank you for this opportunity to discuss the future research prospects of wind and solar energy and the opportunities they provide for advanced technologies.

I'm Peter Green as introduced, I'm Deputy Lab Director for NREL. Prior to coming to NREL, I spent 9 years on the faculty of the University of Texas, another 11 years on the faculty of the University of Michigan; prior to that, I was at Sandia National Laboratories.

NREL for the last 4 decades, since its inception, has made critical contributions to the science that underpins the technology innovation that have led to establishing the now viable wind and solar industries.

Indeed, as Chairman Lamb pointed out, the last few years have seen a rapid expansion of both solar and wind capacity, power generation. He also correctly points out that these industries employ over 350,000 people and together they provide about 8.2 percent of total electricity, in the U.S.

Now, one of the primary reasons has to do with a drop in price and cost, and cost is now on parity with conventional energy production sources, in some cases, a little better. I want to emphasize however, that this is just the beginning. A number of scenarios that people have evaluated will project that conservatively, we need to increase power from both wind and solar by at least order of magnitude over the next decade.

And cost is going to have to come down to much lower levels, in fact one half of where it is at this point; this really sets a bar for where we really need to be. We're not currently able to do that. And perhaps one thing to point to are the solar and energy goals—the R&D goals here are really set by the manufacturers, the plant developers, and utilities. If we are going to increase capacity more than order of magnitude and also decrease prices, there's a lot that needs to be done.

There is a myriad of solar PV technologies which require significantly more research, some include the multi-junction and tandem cells, which are quite effective in terms of efficiency; the perovskites which can be produced, roll-to-roll could be a gamechanger, but there is a lot of work that needs to be done to increase their stability, a lot more research needs to be done.

Solar power—concentrating solar power is another area where in fact, the goal is 5 cents per kilowatt hour and at the same time combined with thermal storage, which is cheaper than batteries, provides significant opportunities. There's a lot of work going on there in China right now but not so much in this country.

I want to now talk about wind power; but with regard to wind power, the goal is that we would like to be able to produce wind from anywhere within the U.S., onshore, offshore, East or West Coast as well as the Great Lakes. We also want to do it at half the current cost. Now, there's a challenge! The International Energy Agency got together the best researchers around to actually put together what the future of wind should look like. An interesting quote from the report, "Realizing the full potential of wind technology will require a paradigm shift in how wind turbines and power plants are designed."

Really what's happened here is that these new wind machines are going to be full-length, almost 250 meters high; higher than the Washington Monument, and there are some challenges. One, what I'd like to do is I'd like to take advantage of the wind resource which is much more rich at higher levels. However, these new huge wind machines are going to have to be lighter and they're going to have to be cheaper, and this is a major challenge.

We don't understand the wind resource in enough detail at that level; this is also going to require more research. The blades are going to be too long so you can't transport them along a highway; so they're going to have to be onsite-manufactured, taking advantage of new manufacturing technologies; that's yet another challenge.

Recycling is another issue. Even more important, the current windfarms underperform and so there's an enormous amount of work to be done to understand the wind dynamics and things to be able to optimize the performance of wind farms.

So I have two final comments to make, the current grid modernization efforts as well as complementary technologies like storages are continuing and certainly they're going to be able to facilitate large amounts of renewable energy in the grid.

And the final point that I really want to make, actually two final points, NREL has spent years going from basic science toward implementation for commercial interactions; this has been part of our DNA since our inception in 1977. The new system, interactive system that DOE has really fostered, where we've got interactions between academia, National Labs, and industry has worked well.

The different DOE funding models worked well! They were responsible for where we are at this point with wind and solar, and I think that this will be quite useful in years to come; we cannot reach those goals without further R&D spending. And again, let me thank you for this opportunity.

[The prepared statement of Dr. Green follows:]

**Prepared Statement of Dr. Peter F. Green
Deputy Laboratory Director, Science and Technology
National Renewable Energy Laboratory**

**For the House Science, Space & Technology Committee
Subcommittee on Energy
Hearing on “Advancing the Next Generation of Solar and Wind Energy
Technologies”**

May 15, 2019

Chairman Lamb, Ranking Member Weber, members of the Subcommittee, thank you for this opportunity to address the future research opportunities for solar and wind energy, and the many benefits these advanced technologies can deliver for our nation.

I am Peter Green, the Deputy Laboratory Director of the U.S. Department of Energy’s National Renewable Energy Laboratory, or NREL, in Golden, Colorado. My career has included more than 30 years in research positions in the academic and national laboratory complex. Prior to coming to NREL in 2016, I was the Vincent T. and Gloria M. Gorguze Endowed Professor of Engineering as well as professor of materials science and engineering, chemical engineering, and applied physics at the University of Michigan. Prior to that I was the B.F. Goodrich Endowed Professor of Materials Engineering and Professor of Chemical Engineering at the University of Texas. My professional career began at Sandia National Laboratories where I was manager of the Glass and Electronic Ceramics Research Department. I am a fellow of a number of societies including the American Physical Society, American Association for the Advancement of Science, the Royal Society of Chemistry and the Materials Research society. I am a former president of the Materials Research Society. I served on advisory boards for the national academies, national laboratories, scientific journals, and universities. My B.A./M.A. degrees are in Physics, from Hunter College, and my M.S. and PhD are in Materials Science and Engineering from Cornell University.

Since my lab, NREL was founded in 1977, we have been proud to contribute to the science and innovation necessary to create vibrant new U.S. industries from what were then just niche players on the energy horizon. In 2018, wind power capacity in the U.S. added 7,588 megawatts, to a fleet that now totals 50,000 commercial-scale turbines with nearly 100,000 megawatts of capacity—about 7 percent of the nation’s electricity. There are more than 100,000 Americans employed in the wind industry, which sees even greater growth in the years ahead.

Solar energy enjoys the same kinds of exciting prospects. The number of solar power installations in the United States surpassed two million this year, or about 1.6 percent of domestic power output. The Solar Foundation estimates the industry has a workforce of nearly 250,000 today, with remarkable potential for expansion into the future.

By 2030, estimates suggest that renewables could contribute a third of our nation's overall electricity generation, an amount forecast to rise to nearly 40 percent by 2040. I believe that given adequate support for a balanced research portfolio, the resulting pipeline of innovation in new materials, technologies, designs, and processes for solar and wind power can usher in a new era for U.S. energy affordability, resiliency, reliability, durability, and security. Ever cheaper supplies of wind and solar power may provide lowest-cost energy for U.S. manufacturing and the use of renewable power to produce renewable fuels. National laboratories, academics, and industry researchers are all working collaboratively on these and related challenges. Recent NREL partnerships with energy giants ExxonMobil and Shell may be a pathway to solving these research challenges.

Solar Energy Research

Foundational science, including chemistry, electrochemistry, materials science, semiconductor physics and computational applications, is enabling innovation across the solar energy spectrum. NREL's longstanding work for the DOE solar program has helped achieve massive cost reductions, increases in performance, and better integration into the existing electric infrastructure. Today, NREL also is working with the U.S. military on lightweight solar materials and applications to enable the computers and communication systems soldiers are using in forward operating environments. Drone systems are likely to use new solar technology to achieve perpetual flight.

Research conducted at NREL and other labs is evolutionary in nature. The multi-junction solar cells used on the Mars rover and many satellites were born out of NREL research several decades ago. While these technologies may be too expensive to employ in terrestrial applications today, we are working on dramatically lowering costs to bring this technology back to Earth.

By design, our research is conducted in partnership and mutual collaboration with industry, other National Labs, and universities across the nation. Our R&D goals are informed by U.S. manufacturers, energy plant developers and utilities, based on their real-world, on-the-ground needs to grow their products, services and business potential. Those partnerships even extend to the most fundamental sciences behind the technologies. In the NREL-led Center for Next Generation of Materials Design, an Energy Frontier Research Center (EFRC) we have worked with the Stanford Linear Accelerator, or SLAC, on fundamental computational materials discovery by design, to develop new materials for new solar energy concepts.

It is essential to pursue breakthrough science focused on improving efficiency, reducing costs, improving durability and reliability and streamlining manufacturing processes, if we are to make the U.S. solar energy industry competitive and profitable. Research on advanced photovoltaic cells and devices should include a range of materials and technologies. For perovskites, we need to continue working toward creating stable and efficient modules, as well as innovative processing concepts to create low-capital-cost manufacturing platforms. For organic solar cells we need to improve efficiency and performance. For silicon, we must reduce costs through research into materials, module designs, and manufacturing systems that are more sustainably based. For thin films, increasing energy efficiency and driving down the cost of manufacturing remain crucial. For so-called III-V (three-five) cells, here again the overarching goal is to pursue lower costs, and still higher efficiencies. For tandem devices, we are closing in on a commercially viable design that meets cost targets at the system level, while demonstrating adequate performance and reliability.

Research should also encompass advanced module and installation designs to improve production output, as well as reduce hardware and installation costs. In the case of the electronics needed at the module level, we need to reduce operational and maintenance costs, while increasing system longevity.

Research in Solar-to-X

As solar power becomes abundant, we look forward to a time when new opportunities to use surplus solar power can increase our nation's economic competitiveness. Looking at the potential of solar beyond the electric grid, we are exploring Solar-to-X technologies, from solar fuels directly from sunlight, to advanced electrolysis and thermal processes. In this realm, research into technologies for solar to create additional products could be revolutionary. Converting solar electricity to something else of value, such as solar-to-fuels, solar-to-hydrogen, or solar-to-chemicals, such as ammonia, has great potential.

To be sure, these technologies today are still in the research stage, but comprise untold opportunities for the future. The technological potential across solar thermochemical, photo-electrochemical, high-temperature electrolysis and photo-thermal platforms, is waiting to be exploited. Thermal solar systems may be an entry into large-scale solar-fuel production, which could cut energy costs for large-scale hydrogen production from water-splitting. These Solar-to-X possibilities could support growth of U.S. manufacturing and other industries, with associated economic and workforce expansion. Sustained research into each of these scientific lanes will be required.

Another research area is "power anywhere," which seeks to take advantage of some of the unique properties of photovoltaic solar, whether it's lightweight, flexible, or portable. That

means not just stationary power sources, but solar installed on a myriad of surfaces, able cover whatever application is available. Finally, solar technology advances also demand more detailed analysis of economics, life cycles, materials availability, and other, indirect but essential factors.

Concentrating Solar Power

Concentrating solar power, or CSP, technology has heading toward systems that can achieve costs of 4-to-5 cents per kilowatt-hour, including 8-to-15 hours of energy storage. The fundamental challenge for CSP research is a thermodynamic power cycle, which requires development of advanced, high-temperature working fluids, alongside thermal energy storage. Moreover, because the solar mirror field essential to CSP systems represents a major cost, coming up with next-generation CSP field designs is crucial as well. We are working closely with industry to reduce solar field costs by using advanced manufacturing concepts and new materials.

Solar energy will be an enormous economic opportunity in the years ahead. To lower initial costs and maximize return on investment in this multi-billion-dollar industry, solar technologies need to perform optimally and reliably across their intended lifespans. Beyond the value proposition that solar installation revolves around, longer-term consideration of lifecycle costs, and ultimately, opportunities for economically viable material recycling and reuse, are of the highest order. In today's developing circular economies for industries and materials, we want to minimize use of hazardous inputs and extract value from materials recovered and recycled at end of life.

Wind Power Research

Federal R&D investments into collaborative R&D between national laboratories, universities, and industry have largely been responsible for the major advances in wind energy and its current impact. Today, research proceeds in a wide range of wind-related topics. Just the advancing technologies in wind machine control systems could, for instance, optimize the overall efficiency of entire multi-turbine wind farms, realizing hundreds of millions of dollars in savings to the industry, and consumers. Our eventual goal is to use a combination of foundational scientific understanding to drive innovations to produce wind power at half the cost of current wind generation, operating anywhere in the United States.

NREL contributed extensively to a just-released International Energy Agency study that brought together more than 70 wind energy experts, and which lays out "A Grand Vision for Wind Energy Technology." The report concludes that "realizing the full potential of wind technology will require a paradigm shift in how wind turbines and power plants are designed, controlled, and operated. Notwithstanding the accomplishments ... to date in driving down costs and increasing

performance, there is still an immense opportunity for innovation to enable continued expansion of wind power.”

Underscoring the complexity of the R&D challenges, the report divided the most promising research requirements into these categories: turbine design and technology, manufacturing, atmospheric science and forecasting, plant controls and operations, grid integration and, finally, R&D that is specific to off-shore technologies. Each of these areas holds promise in significantly increasing deployment potential and reducing costs of wind energy generation.

Turbine Design and Technology

There is continuing opportunity to make future wind turbines even bigger and more flexible than previous technological generations to access greater power at higher elevations, 200-250 meters, and to achieve the additional economies of scale that can be achieved from these gigantic machines. Researchers and industry alike project that turbines need to increase their size into the 200-meter-plus diameter range, set atop towers that need to extend over 150 meters high (total height of greater than 800 feet) to achieve the economies of scale for significant cost of energy reduction.

Putting the R&D challenge into perspective, it will also make wind machines the largest rotating machines ever built. We have yet to establish the boundaries of safe operation for such turbines. Recent research results indicate that at this scale, some of the basic aerodynamic assumptions upon which the current generations of efficient commercial turbines have been based, may no longer be valid.

As offshore wind turbines continue to increase in size—with rotor diameters larger than two football fields—they present unique research challenges that require the combined understanding of wind flow aerodynamics through the rotor, hydrodynamic forces from waves and currents acting on the structure, advanced materials, and controls. Moreover, these machines must be flexible to survive extreme weather events, like hurricanes or icing events, that are prevalent along the East Coast and in the Great Lakes, where offshore wind energy deployments are planned. Floating offshore systems, which promise to enable wind energy in large areas of the ocean off the East and Pacific Coasts in water depths of 50 meters or more, present additional research challenge because they have additional sources of motion in the turbine platform anchored to the sea floor by mooring cables. Because floating systems are tethered by cable moorings to buoyant platforms, the greater turbine motions which need to be moderated with advanced control methods, lightweight material designs, and new hydrodynamic platform configurations.

Turbine Manufacturing R&D

It may come as surprise that modern wind turbine blades still use materials and processes similar to those used for machines of the 1990s, based as they are on low-cost composite fibers and durable epoxy resins. Research into tailored matrix, fiber reinforcement, and core materials, as well as adhesives and innovative ways of manufacturing, such as 3D printing, is needed to improve the strength and stiffness, and reduce the weight—all at very low cost. Current blade costs are more than an order of magnitude less, pound for pound, than aerospace materials used for similar functions. Research is needed for these costs to continue to come down.

An opportunity to improve blade manufacturing is the transition to thermoplastic resins, if they could be proven for blade applications. This would allow the “welding” of the composite structural elements, and this is critical, the recyclability of blades at the end of their commercial life. Beyond blades, other components will also require distinct solutions in materials, including the tower; load-bearing supports; sensors for the machine and the environment; mechanical drive components, such as bearings and lubricants; and electrical drivetrain components, such as generators.

The on-site manufacturing of larger blades, thereby avoiding transportation barriers of blades from manufacturing sites to wind farms, is important. Development of reliable processes to improve blade manufacturing, involving thermoplastic resins, has important benefits. This would enable “welding” of the composite structural elements, and moreover, the recyclability of blades at the end of their commercial life.

Atmospheric Science and Forecasting

The evolving scale of wind machines is reaching farther than many, if not all, other large-scale dynamic systems ever built and operated. The natural dynamics of the atmospheric flows that power machines at this scale needs to be better understood. Clearly, the methods we have used historically to understand and predict the larger scale physics of the weather is no longer sufficient, as we will be operating in zones of the atmosphere where less is known about the dynamics of the wind, which creates new needs for research into the wind resource.

Since the energy comes from the weather, and designing turbines depends on the how that weather translates into small scale turbulence, these scales must be linked based on a more comprehensive understanding of the nature of the transition. In addition to accurately capturing the deep dynamics between weather and wind plants, there is a need to understand the physics of the wakes, the downwind zones of low-speed air created when energy is extracted from the wind. The new science of data analytics is opening the door to innovative ways to use both turbine and

weather data to not only predict future power generation, but to develop control systems that manage the wakes and increase intra-plant power productivity.

Energy Storage and Grid Integration

With penetration of wind and solar generation growing, it is vitally important that we continue to develop energy storage technologies. Energy storage today is revealing real-world potential for resolving many of the challenges associated with variable wind and solar resources.

Different storage technologies require diverse technology solutions, because storage needs change depending on how much and how long storage is needed. For example, stationary storage, which increasingly accompanies solar energy systems on the grid, is a field ripe for innovation. Energy storage research pivots around the three key research goals: higher energy density, longer life, and enabling greater adoption of energy storage. Scientists and engineers are especially focused on technologies at the intersection of these three goals, such as low cobalt cathodes, solid state electrolytes to enable lithium metal anodes, and engineering analysis and high-performance computing modeling.

As solar and wind generation expands, and localized, distributed energy systems proliferate, our electric grid must be modernized to ensure safe, reliable, and affordable electric power to all Americans. To meet this challenge, NREL and other research institutions are engaged in foundational science research in autonomous energy systems, or AES, that will allow for the real-time, monitoring, optimization, and control of integrated energy systems. Groundbreaking AES technology studies are underway at NREL's Energy Systems Integration Center, and at our new Flatirons Campus, a one-of-a-kind facility that provides utility-scale grid integration and energy systems research and testing. Plans have been approved to employ AES control concepts at 1–2MW scale with a range of devices in the Energy Systems Integration Center and to build out 10–20MW of integrated system assets at the Flatirons Campus. In the long-term, this research will provide the opportunity to evaluate autonomous control of multiple generation, storage, and load technologies at utility-scale to enable future energy systems.

Improving the technologies behind the power electronics across our energy systems holds great promise. Solar and photovoltaic systems and wind turbines all depend on a diverse set of power electronics to connect to the grid. Operational control systems likewise depend on power electronics. Improving the cost, efficiency, and reliability of these electronic control systems can benefit individual installations, and the entire national grid.

Energy system resilience and cybersecurity are also critically important research areas. Identifying, isolating, responding to and protecting against natural and man-made threats to our energy systems is paramount.

In Conclusion

If solar and wind power are to fulfill their potential as critical drivers to achieve our nation's future energy goals, a balanced portfolio of research is required. The goal of the research community and of industry is to enable multiple terrawatts of wind and solar power by 2030. This is projected to be at the lowest cost of electricity ever produced, without subsidy, and with minimal environment impact. This will not be possible without a robust federal commitment to solar and wind R&D. Along with new technologies, we are already seeing that new industries, and new business models for established industries, will transform energy production and use in the decades ahead. The scientists and engineers in laboratories and across energy industry facilities nationwide provide the United States with unique and unparalleled capabilities to be the global leaders in this rapidly changing energy sector—one which powers virtually all other areas of economic activity, not to mention our daily lives. These research endeavors are even more compelling when we consider the fact that when it comes to solar and wind, the United States is fortunate to be home to the world's most abundant resources for each.

Peter F. Green

Peter F. Green is the Deputy Laboratory Director for Science and Technology, and the Chief Research Officer, for the National Renewable Energy Laboratory (NREL). Green began his career at Sandia National Laboratories in 1985 where he later became manager of the Glass and Electronic Ceramics Research Department, from 1990-1996. In 1996 he moved to the University of Texas, Austin, where he became Professor of Chemical Engineering, and was the B.F. Goodrich Endowed Professor of Materials Engineering. Later in 2005 he was recruited to the University of Michigan to become Chair of the Department of Materials Science and Engineering. Green was also the Vincent T. and Gloria M. Gorguze Endowed Professor of Engineering, and also Professor of Materials Science and Engineering, Chemical Engineering, Applied Physics. He was also the Director/Principal Investigator of the DOE Energy Frontier Center (EFRC) –Center for solar and thermal energy conversion (CSTEC).

Green is a former President of the Materials Research Society (MRS). He serves, and has served, on advisory boards for Government Laboratories, Universities, the National Academies, private foundations and peer reviewed scientific journals. Former memberships include: National Academies Board of Physics and Astronomy (BPA), National Academies Board on Army Science and Technology (BAST); chair of the National Academy Solid State Sciences Committees; chair of the National Academy's Panel on Neutron Research; advisory board for the American Chemical Society (ACS) Petroleum Research Fund (PRF). Green was a member of the National Institutes of Standards and Technology (NIST) visiting committee for advanced technology (VCAT). He is currently a member of advisory boards for Cornell University, Massachusetts Institute of Technology, Princeton University and Sandia National Laboratories.

Dr. Green is a Fellow of the American Association for the Advancement of Science (AAAS), Fellow of the Materials Research Society, Fellow of the Royal Society of Chemistry (UK), Fellow of the American Ceramics Society and Fellow of the American Physical Society. Green attended Hunter College, N.Y., from 1977-1981, where he earned B.A. and M.A. degrees in Physics. He earned a Master of Science and a doctorate in Materials Science and Engineering from Cornell University in 1983 and 1985, respectively.

Chairman LAMB. Thank you very much, Dr. Green.
Ms. Hopper?

**TESTIMONY OF ABBY HOPPER, ESQ.,
PRESIDENT AND CEO, SOLAR ENERGY
INDUSTRIES ASSOCIATION**

Ms. HOPPER. Great. Good morning. Chairman Lamb, Ranking Member Weber, and Ranking Member Lucas, and Members of the Subcommittee, thank you so much for having me here today. It's an honor to be here. My name is Abby Hopper. I am the CEO and President of the Solar Energy Industries Association or SEIA. I think everyone here has a great acronym. That's mine, SEIA, and we are the national trade association for the American solar energy industry. We have 1,000-member companies in every State across the Nation, and as you've heard and as we never get tired of telling you, we have about 250,000 Americans working in our industry. It is a \$17-billion-a-year industry.

There is bipartisan support for the solar industry and with policymakers in both parties at both the Federal, the regional, the local, the State level, every level of government advancing this clean, competitive, job-creating energy source. The modern solar industry has benefited tremendously from technology that the Department of Energy has helped bring to market. This has included solar-plus storage, which has achieved higher asset utilization; smart inverters for flexible power control; better communications and data analytics; and improved codes and standards. And so SEIA supports the Committee's draft bill to authorize and fund solar research.

So allow me to share our industry's vision with you and explain why a continued investment by the Federal Government in research and development is critical to making that vision a reality. You've heard lots of statistics. My particular solar one is that solar now currently represents about 2.3 percent of U.S. electricity generation today. We have established an aggressive goal for ourselves to make solar account for 20 percent of all U.S. electricity generation by 2030, thereby making the 2020s the solar-plus decade, and we'll talk a little bit about why the plus is there.

To get there we're going to need to install an average of 39 gigawatts each year through the 2020s, including 77 gigawatts in 2030 alone. We'll need an average annual growth rate of 18 percent and cost reductions, as the good doctor said, across all market segments by nearly 50 percent. So if we achieve this growth together, we'll build more systems annually than we have built to date.

And there will be 600,000 solar jobs by—in 2030, and that's more workers than every single U.S. company except for Walmart, more than the utility industry, and more than the mining, oil, and gas extraction industries combined. So that level of employment growth will mean not just a larger but a more diverse workforce, which will benefit from Federal job training support. We must ensure that people of all backgrounds, genders, and abilities have access to both solar energy jobs and the solar energy itself. If we achieve our 20 percent goal by 2030, our industry will add more than \$345 billion to the U.S. economy.

So while there are many notable areas for further research, to reach this 20 percent solar by 2030, I'd like to highlight a couple of areas that we think are critically important. First, soft costs, those non-hardware costs of permitting, inspection, interconnection, customer acquisition, and labor are increasingly representing a larger share of the cost of solar energy system. More efficient permitting can save consumers about \$1 per watt or roughly 40 percent on the cost of a residential energy system. This includes direct costs such as fees and indirect costs such as time spent on applications and inspections. These issues will impact both established and emerging markets alike.

Second, using grid integration should continue to be a top priority. The grid must be able to handle this intermittent and variable generation, and investing in infrastructure upgrades is necessary to hit these targets. We also have to invest in cybersecurity technologies for photovoltaic and other grid interactive systems today that will ensure that as more of these come online that we can recover faster and our systems are more secure.

Third, we are supportive of efforts to advance U.S. solar manufacturing. The United States has the best National Labs in the world, and I'm not just saying that because Dr. Green is sitting next to me. I do believe that. Leveraging these resources is essential to improving the competitiveness of U.S. solar manufacturers and the long-term health of the U.S. solar industry.

And last and importantly, we must fund late-stage technologies and field demonstrations. As just one example, energy storage will be a vital part of achieving 20 percent solar by 2030, but few utilities will incorporate large volumes of storage unless they understand how those systems will interact with each other.

So thank you for your time and your continued support of the solar industry. The vision I've outlined is bold but certainly achievable. We're working to overcome the challenges we must face to make the 2020s the solar-plus decade, but we cannot do it alone. Research and collaboration with the Federal Government will be key to our success, and that means strong authorization language and funding to make sure it happens.

I look forward to answering the questions you may have.

[The prepared statement of Ms. Hopper follows:]

**Testimony of Abigail Ross Hopper, Esquire
President and CEO
Solar Energy Industries Association**

US House of Representatives Committee on Science, Space, and Technology
Subcommittee on Energy
Advancing the Next Generation of Solar and Wind Technologies
May 15, 2019

Chairman Lamb, Ranking Member Weber and members of the Subcommittee, thank you for having me here today and for your interest in solar energy.

I am Abigail Ross Hopper, president and CEO of the Solar Energy Industries Association (SEIA). SEIA is the national trade group for America's solar energy industry with 1,000 member companies. Approximately 250,000 Americans work in the \$17 billion solar industry.

There is bipartisan support for solar, with policymakers in both parties taking action at the federal, state and local level to advance this clean, competitive, job-creating energy source. The modern solar industry benefits from technology that the Department of Energy helped bring to market. This includes solar plus storage which has achieved higher asset utilization, smart inverters for flexible power control, better communications and data analytics, and improved codes and standards. SEIA's companies benefit from the products of federal research and development, and we support the Committee's draft bill to authorize and fund solar research.

The economic opportunity proffered by the growth of the solar industry is enormous, and the stakes couldn't be higher. My testimony will address the vision we must have and the targets we must hit to tackle the massive challenges this moment demands. We are determined to do our part to meet climate targets. That's why the solar industry is developing a roadmap for exponential growth in the 2020s. Federal research and development is an essential element to helping us reach these ambitious goals.

The 2020s: The Solar+ Decade

Solar represents 2.5% of U.S. electricity generation today; the industry has established an aggressive goal to make solar account for 20% of all U.S. electricity generation by 2030. Solar won't be the only source of clean new electricity, but it will be the dominant new source.

To get there, we're going to need to install an average of 39 GW each year through the 2020s, including 77 GW in 2030 alone. We'll need an average annual growth rate of 18% and cost reductions across all market segments by nearly 50%.

If we achieve this growth together, we will create 350,000 additional jobs and build more systems annually than we have installed to date. There will be 600,000 solar jobs in 2030. That's more workers than every single U.S. company except for Walmart, more than the utility industry, and more than the mining and oil and gas extraction industries combined.

This level of employment growth will mean not just a larger, but a more diverse workforce, which will require federal job training support. The need for a larger pool of workers is just one reason I have made diversity and inclusion one of my top priorities. We must ensure that people of all backgrounds,

genders, and abilities have access to both solar energy jobs and solar energy itself. That in turn will lead to a stronger, more creative, more effective and more successful workforce in the next decade.

If we achieve our 20% goal for solar by 2030, our industry will add more than \$345 billion into the U.S. economy over the next ten years, reaching \$53 billion annually. Achieving this goal will also have an impact on Americans every day who will enjoy greater choice, lower cost energy bills and cleaner air.

Solar technology has come a long way in the 45 years my organization has existed, but the next decade will require radical market transformation, an overhaul of the way our power grid operates, and aggressive collaboration to make the industry's vision a reality. We are going to need Solar+ Storage, Solar+ Grid Modernization, Solar+ Cybersecurity and Solar + lower soft costs, to name a few.

Where We Are Now

Think about this: ten years ago, there was 1.5 gigawatts (GW) of solar installed in the United States and solar represented less than 0.1% of U.S. electricity supply. The main problem at the time? Costs. Recognizing that challenge, the Solar Energy Technologies Office (SETO) established its own aggressive goal—to make solar cost competitive with fossil fuels by 2020.

The private sector and DOE rallied around this big cost-cutting goal. For the past decade, the office has funded research programs that have helped bring down costs by 70%. Together, three years ahead of schedule in 2017, the office announced that the solar industry achieved its utility-scale solar cost target. The U.S. economy saw immediate gains from this work and your home states are benefitting from the increased solar activity made possible by advanced solar research:

- In Pennsylvania, there are more than 550 solar companies consisting of manufacturers, installers, developers and other solar related businesses. In the 17th district of Pennsylvania alone, there are 26 solar companies. There are more than 50,000 homes powered by solar in Pennsylvania. The current total solar investment in the state amounts to \$1.65 billion and eight active SETO-funded projects receiving \$12 million.
- The state of Texas stands 5th overall for the most solar for any state in the United States. Solar powers nearly 350,000 homes in Texas. There are approximately 650 solar companies employing nearly 10,000 people in the state. Texas is poised to become a national leader in solar energy in the next 5 years. There are 10 active SETO-funded projects receiving \$19.6 million.
- In South Carolina, nearly 80,000 homes are powered by solar. The state is home to 80 solar companies and solar provides approximately 3,000 jobs. Several retailers have gone solar, with Target having installed one of the largest corporate photovoltaic systems in the state. There remains an enormous amount of capacity in the pipeline, with more than 805 MW of solar projected to be brought online over the next 5 years. There are two active SETO-funded projects receiving \$2.4 million.
- Illinois boasts 366 solar companies located in the state and nearly 17,000 homes are powered by solar. Illinois is a growing solar market that has benefited from a strong renewable portfolio standard that requires that 25 percent of electricity be generated by renewable sources by 2025. The amount of solar capacity installed in Illinois is expected to grow by more than 1,700% over the next five years. There are 15 active SETO-funded projects receiving \$17.6 million.
- Arizona ranks 3rd in the nation overall for the most solar. Arizona has more than 550,000 homes powered by solar and more than six and a half percent of the state's electricity is produced by solar. Arizona has more than 450 solar companies and the state ranks 7th in the US for the most solar growth expected in the next 5 years. Arizona boasts over 7500 solar jobs. In the 5th district

of Arizona alone, there are 32 solar companies. There are over 20 active SETO projects receiving more than \$25 million, with much of that funding going to Arizona State University.

At the close of this decade, we now have 2 million solar installations across the country and last year we hit 70 gigawatts of installed capacity. That is a 4,700% increase from 2010. SETO's 2020 cost-cutting goal put a stake in the ground and jumpstarted research activity in the solar industry. We're here to do that again.

The Role of Federal Research

Federal investment in solar research and development has long paved the way for commercialization of technologies. Federal solar research has made the United States a global leader in solar technology development. Additionally, as discussed above, the dramatic cost declines in the 2010s happened because of the vision of SETO in setting, and then investing federal research dollars, into meeting that goal. The nation needs continued strong investment in solar research to ensure that the United States remains a global leader in solar technology development and cost reduction.

Through competitions and aggressive milestones built into each project, federally supported research programs bring together diverse partners and encourage efficient and effective research. In some cases, this research can help companies right away. From permitting and finding customers to addressing siting for both residential and utility-scale installations, SETO helps solar companies build businesses faster. For example, finding customers is a major cost for nearly every residential solar company. EnergySage, a SEIA member company, received early support from SETO to build its online solar marketplace which links homeowners who want to go solar with companies that can meet their needs. In this way, SETO research dollars help support hundreds of companies.

SETO also supports startups like SEIA member Aurora Solar which used a research award to develop a sophisticated 3-D modeling program that precisely calculates the solar potential of a building's roof. This research award and the technology it supported has allowed Aurora Solar to grow its customer base and become a thriving solar software company.

SETO and the national labs also provide unbiased, relevant technical information and analysis that will undoubtedly contribute to the industry achieving 20% solar by 2030. Here's just one of many examples of why federal investments in solar research are valuable.

Recently, parts of Hawaii had relatively high solar penetration on the grid compared to other parts of the United States. The utility shut down all additional interconnections. However, with funding from SETO, National Renewable Energy Lab (NREL) with support from the solar industry and Hawaiian Electric (HECO), conducted data modeling and was able to show that Hawaiian Electric could host more than twice as much as they were currently without problems.

As states are dealing with physical infrastructure issues that are more advanced, utilities must be sharper in their analysis. Congress needs to make sure we provide not only funding so that there is more accessibility to this kind of data modeling, but also direct the development of standards incorporating the use of that data so utilities don't just throw up their hands and say "everything has to stop" when it comes to connecting more solar to the grid.

That's why federal support is uniquely valuable. Without federal funding for state-of-the-art data modeling, technology and knowhow, this is the type of risk and expense private industry usually cannot take on by itself. Federal research provides holistic leadership to support the pipeline of research the solar industry needs to meet our ambitious goals. Further, national laboratories such as NREL, Lawrence Berkeley National Laboratory, Sandia National Laboratories, Oakridge National Laboratory, and others serve as critical independent messengers to perform and disseminate complex analyses and they have earned the trust of solar and utility executives.

Solar Research for the Solar+ Decade

While there are many notable areas for further research, to reach 20% solar by 2030, the committee should prioritize funding for the following approaches and areas of solar research.

Addressing Soft Costs Through Targeted Research and Programming

Soft costs—the non-hardware costs like permitting, inspection, interconnection, customer acquisition, and labor—are increasingly representing a larger share of the cost of a solar energy system. Funds for these programs have continually been zeroed out by the Administration and we ask that you not only continue funding these programs but increase funding.

Let me give you an example. Siting major utility-scale projects presents a significant risk for developers and requires extremely technical information about the geographic and other characteristics of a possible site. Getting this right is critical and can lead to major cost savings. SEIA member company 7X Energy partnered with SETO to allow the company access to Smart Power Maps, a highly sophisticated software platform that GeoCF developed with support from SETO. This platform combines numerous data sets including geospatial and other characteristics to evaluate potential utility-scale development locations and acquire necessary permissions for development.

As the Department has done for other technologies, SETO has funded and can continue to fund research and analysis to overcome siting and permitting challenges associated with building large facilities, including producing materials that can help stakeholders understand the benefits of having those facilities located nearby and helping put to rest fears about those facilities.

Another way to cut soft costs is streamlining permitting and interconnection processes. More efficient permitting could save customers, \$1 per watt (roughly 40%) on the cost of a residential solar energy system. This includes direct costs such as fees and indirect costs such as the burdensome application process, the time it takes for an inspection and the high cost of losing customers who are frustrated with long approval times. These issues impact both established and emerging markets alike. Solar Automated Permit Processing, or SolarAPP, is an initiative to create a simple, standardized, no-cost online platform for local governments, that not only reduces costs but improves workflows for local governments and allows building officials to focus their efforts where they are needed most. We urge the committee to fund SETO to advance collaborative permitting and interconnection reform efforts like the SolarAPP.

Prioritizing the Security, Resilience, and Efficient Operation of the Grid

Easing grid integration should continue to be a top priority. If the solar industry achieves 20% solar by 2030, it's estimated that 15 million solar systems will be connected to the grid including hundreds of gigawatts of large-scale projects. That 20% won't be evenly distributed across all 50 states. Some states might have 70% solar while others might have 5% or 10%.

The grid must be able to handle this influx of variable generation and invest in infrastructure upgrades necessary to hit the target. Investing in cybersecurity technologies for photovoltaic and other grid-interactive systems today will ensure that the systems coming online are not only more secure but can recover faster if there is a cyber or physical disturbance.

Advanced Manufacturing

We are also supportive of efforts to advance U.S. solar manufacturing. DOE's program to reward competitors with support from U.S. national laboratories and regional incubators is a pro-competitive way to fund R&D efforts.

The U.S. has the best national laboratories and start-up incubators in the world. Leveraging these resources is essential to improving the competitiveness of U.S. solar manufacturers and the long-term health of the U.S. solar industry.

We've seen hundreds of millions of dollars in recent investments in large-scale solar manufacturing, including new manufacturing plants in Georgia, Florida, Mississippi, and Ohio. As our industry continues to expand, opportunities for new U.S. solar manufacturing will grow as well. Getting to 20% solar energy by 2030 will enable a domestic market large enough to support competitive, scaled solar supply chains in the U.S., from panels to steel and aluminum mounting structures.

Storage and Later Stage Demonstration and Deployment

Over the years, we've seen a decline in funding for later stage technologies and field demonstrations. You simply cannot secure customers for a new technology without first verifying that it works as expected. In addition, energy storage will be a vital part of achieving 20% solar by 2030. But few utilities will incorporate large volumes of storage without performing demonstrations. We need to know how these systems will interact with one another and grid operators must be able to effectively use their solar and storage assets. We urge you to support funding for later stage projects.

Conclusion

Thank you for your time and continued support of the solar industry. The vision I have outlined is bold, but achievable. We're calling on the solar industry to once again come together to overcome the systemic challenges we must face in order to make the 2020s the Solar+ Decade. But we can't do it alone—research and collaboration with the federal government will be key to our success and that means strong authorization language and funding to make sure it happens. Our first steps into the Solar+ Decade start here.

I look forward to answering any questions you may have.



Abigail Ross Hopper, Esq.

Abigail Ross Hopper is the President and CEO of the Solar Energy Industries Association, the national trade organization for America's solar energy industries. She oversees all of SEIA's activities, including government affairs, research, communications, and industry leadership, and is focused on creating a marketplace where solar will constitute a significant percentage of America's energy generation.

Before joining SEIA, Abby was the Director of the Department of Interior's Bureau of Ocean Energy Management, where she led the agency that oversaw the leasing and development of all offshore energy, from oil and natural gas to offshore wind.

She served formerly as the Director of the Maryland Energy Administration (MEA), serving as acting beginning in 2012, and then as Director starting in June 2013. She also served concurrently as Energy Advisor to Maryland Gov. Martin O'Malley since 2010. In those roles, she had significant engagement with the state's electric distribution utilities on matters ranging from resiliency and reliability of the grid to multiple mergers of the state's utilities.

Abby previously spent over two years as Deputy General Counsel with the Maryland Public Service Commission. Before embarking on a career in public service, Abby spent nine years in private practice.

Abby graduated Cum Laude from the University of Maryland School of Law and earned a Bachelor of Arts Degree from Dartmouth College. She is the very proud mom of three children and loves to read, run, do hot yoga and lay on the beach in her (not so free) time.

Chairman LAMB. Thank you, Ms. Hopper.
Mr. Stein?

**TESTIMONY OF KENNY STEIN, ESQ.,
DIRECTOR OF POLICY,
INSTITUTE FOR ENERGY RESEARCH**

Mr. STEIN. Yes. Mr. Chairman, thank you for the opportunity to participate in the Subcommittee hearing on the Federal Government's involvement in solar and wind energy research. My name is Kenny Stein. I'm the Policy Director for the Institute for Energy Research. We're a free-market organization that conducts research and analysis on the functions, operations, and government regulation of global energy markets.

The purpose of Federal Government funding for research in any industry should be limited and clearly defined. The justification for such funding is that research in emerging or novel technologies would not otherwise be provided by private interests, whether companies or individuals. This is a reasonable role for the government to play. However, this can't be a license to spend money. Federal support should not go to projects that private interests already have a clear incentive to develop.

Far too often, it's the case that the Federal Government provides grant money to companies to subsidize activities that they would already be undertaking. The content of the discussion drafts for this hearing slips into precisely this error. Wind and solar generation are widespread and well-understood. Utilities and independent generators across the country have announced large targets for investments in increasing wind and solar installations, some of which were mentioned by the previous witness. This action is being taken in response to regulatory and consumer demand.

This investment record doesn't suggest a shortage of private-sector funding or commitment to wind and solar generation. The companies making these investments already have market and regulatory incentives to, quote, "increase efficiency, reliability, security, and capacity of wind and solar generation," which is just quoting the first mission bullet of the discussion draft.

Both the wind and solar industries are mature industries with plenty of private-sector interests and investment in innovation and deployment. We're not talking about nascent or speculative industry. The need for Federal funding at all is pretty debatable to put it mildly. If Federal money is still required at this point, the question must be asked, is there ever going to be a point where enough is enough?

Given the already high rate of wind and solar investment, it's hard to see how more Federal intervention could possibly be beneficial. In fact, a heavier Federal hand could end up limiting growth and innovation. The Federal Government is slow and process-constrained as it is, cannot adjust rapidly to technological developments. As new operating processes or products enter the market, it can be left funding older, obsolete initiatives. Indeed, Federal interference of this sort envisioned by these discussion drafts can actually lead an industry to spend its time trying to meet Federal benchmarks for grants rather than asking the question whether an

alternative might make more sense, which could ironically actually limit innovation.

The best example of an appropriate role for the Federal research funding can be found in the earliest days of solar energy generation. Early solar panels with poor efficiency found little uptake for terrestrial resource uses. However, the burgeoning space program identified solar as a potential energy source for spacecraft. Government funding from NASA then helped develop solar technology to the point where it's usable in space applications, and then, years later, solar companies built on that foundation to develop the generation technologies that are now being applied to terrestrial electricity generation.

The lesson here is that the Federal Government didn't choose a solar technology and then try to commercialize it or reduce its costs. The basic technology was developed for a specific national purpose with private innovation later funding applications for the private market. This is how the process should work. The Federal Government does not have the characteristics or competency to be a startup accelerator, but it can effectively provide a base level of data and information for private innovators to build on.

Thus, a better path forward for Federal research spending would be focusing on the original mission that I suggested above, funding emerging or novel technologies and applications not otherwise supported by private interests. One example of this kind of focus is the National Renewable Energy Laboratory research into the use of perovskite materials mentioned earlier in solar cells. This is the kind of basic research the Federal Government should be funding, leaving private entities to determine the most useful applications of these discoveries. There is a legitimate Federal role in supporting such basic research that has the potential to improve the overall well-being of the American people or as required to meet a specific Federal need.

Note that this is not just a branding exercise with anything called early stage or basic coming eligible for funding. Federal research spending should focus on truly novel technologies or applications. Further, this should not just be a license to spend more money. Clearly, focusing Federal priorities means discarding some spending areas sometimes to hone in on research at, for example, the National Labs or universities, the case where less can actually be more effective.

The premise underlying these discussion drafts then in my opinion is unsound. Mature industries like the wind and solar generation sectors with extensive and dynamic economic activity are not in need of Federal interference, however well-intentioned. While basic research is a reasonable Federal role, responsibility for later phases of the business cycle such as commercialization or deployment is best left in the hands of the industry itself. Thank you.

[The prepared statement of Mr. Stein follows:]



Testimony before the House Science, Space, and Technology Committee – Energy Subcommittee

Hearing on: Advancing the Next Generation of Solar and Wind Energy Technologies
Wednesday May 15, 2019

Kenneth Stein
Policy Director, Institute for Energy Research

Mr. Chairman, thank you for the opportunity to participate in this Subcommittee hearing on federal government involvement in solar and wind energy research.

My name is Kenny Stein, I am the Policy Director for the Institute for Energy Research, a free-market organization that conducts research and analysis on the functions, operations, and government regulation of global energy markets.

The purpose of federal government funding for research in any industry should be limited and clearly defined. The justification for such funding is that research in emerging or novel technologies would not otherwise be provided by private interests, whether companies or individuals. This is a reasonable role for the federal government to play; however this cannot be a license to spend money. Federal support should not go to projects that private interests already have a clear incentive to develop. Far too often it is the case that the federal government provides grant money to companies to subsidize activities that they would already be undertaking.

The content of the discussion drafts for this hearing slips into precisely this error. Wind and solar generation are widespread and well understood. Utilities and independent generators across the country have announced large targets for investments in increasing wind and solar installations. This action is being taken in response to regulatory and consumer demand. This investment record does not suggest a shortage of private sector funding or commitment to wind or solar generation. The companies making these investments already have market and regulatory incentives to increase “efficiency, reliability, security and capacity” of wind and solar generation, to take just the first mission bullet of the discussion drafts.

Both the wind and solar industries are mature industries, with plenty of private sector interest and investment in innovation and deployment. We are not talking

about a nascent or speculative industry. The need for federal funding at all is debatable to put it mildly. If federal money is still required at this point the question must be asked whether there is ever a point where enough will be enough.

Given the already high rate of wind and solar investment, it is hard to see how more federal intervention could possibly be beneficial. In fact, a heavier federal hand could end up limiting growth and innovation. The federal government, slow and process-constrained as it is, cannot adjust rapidly to technological developments. As new operating processes or products enter the market, it can be left funding old or obsolete initiatives. Indeed federal interference of the sort envisioned by these discussion drafts can lead an industry to spend its time trying to meet federal benchmarks for grants rather than asking the question whether alternatives might make more sense, ironically limiting innovation.

The best example of an appropriate role for the federal research funding can be found in the earliest days of solar energy generation technology. Early solar panels with poor efficiency found little uptake for terrestrial uses. However, the burgeoning space program identified solar as a potential energy source for spacecraft. Government funding from NASA helped develop nascent solar technology to the point where it was usable in space applications. Years later, solar companies built on that foundation to develop the generation technologies that are now being applied to terrestrial electricity generation.

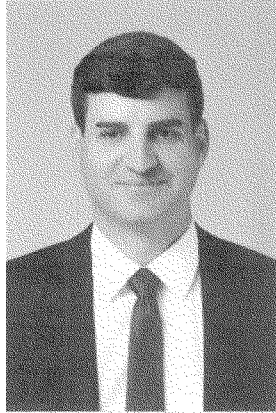
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The premise underlying these discussion drafts is unsound. Mature industries like the wind and solar generation sectors with extensive and dynamic economic activity are not in need of federal interference, however well intentioned. While basic research is a reasonable federal role, responsibility for later phases of the business cycle such as commercialization or deployment is best left in the hands of the industry itself.

IER INSTITUTE FOR
ENERGY RESEARCH

Kenny Stein is the Director of Policy for the Institute for Energy Research. He spent many years working for Senator Ted Cruz of Texas in various roles, including as Legislative Counsel on Capitol Hill, covering energy, environment and agriculture issues, and as Policy Advisor for the Cruz presidential campaign. He has past experience in political roles on national and state campaigns and additional policy roles with free market organizations like FreedomWorks and the American Legislative Exchange Council.

Kenny received his Juris Doctorate from the University of Houston and his B.A. in International Relations from American University. A native Texan, he continues to root for his hometown Houston professional sports teams.

Areas of Expertise: Domestic and international energy policy, environmental regulation and policy, federal land management policy, federalism, legislative analysis

For media inquiries, contact Erin Amsberry at eammsberry@ierdc.org

Chairman LAMB. Thank you, Mr. Stein. Mr. Kiernan?

**TESTIMONY OF TOM KIERNAN,
PRESIDENT AND CEO, AMERICAN WIND ENERGY ASSOCIATION**

Mr. KIERNAN. Chairman Lamb, Ranking Member Weber, Members of the Committee, Ranking Member Lucas, thank you very much for the opportunity to testify. Again, Tom Kiernan, CEO of the American Wind Energy Association representing approximately 1,000-member companies, everything from the turbine manufacturers, the supply chain, the developers of the windfarms, the owner-operators, the researchers, consultants, et cetera.

Wind energy is an American success story. We are currently providing, as was mentioned, 114,000 jobs, and we are either the number-one or the number-two fastest-growing profession, the wind turbine technician, the fastest-growing profession in the country. I'll point out my colleague Abby Hopper often mentions the solar technician is either the first or second. We kind of go back and forth, an important point to note.

Wind energy is also playing a key role in lowering the cost of electricity to consumers. Per third-party analysts, wind energy is the cheapest source of unsubsidized of new electricity on the grid, and in many parts of the country, actually we're cheaper than the marginal cost of existing power grids.

We're also—speaking of rural America, we are also providing \$1 billion annually to rural America whether it's through State and local taxes or land lease payments to farmers.

Another observation I think it was mentioned, we are operating in all 50 States, 500 manufacturing facilities, or having windfarms in those 500 different manufacturing facilities, and we are in 69 percent of all congressional districts, either manufacturing facility or windfarm.

And last, we are reliably on the grid. Six States currently produce at least 20 percent of all their electricity from wind energy, and there are periods of time in some States where we're at 50, 60, or 65 percent of the electricity in that State for a period of time is reliably provided by wind energy.

And then there's the offshore wind energy industry that is blossoming right now with another 8 to 10 gigawatts of wind energy offshore in the next decade.

I'd like to now talk about the really important role of DOE's Wind Energy Technology Office in this American success story. They have been key in the R&D side of it, the innovation and the collaboration, especially on onshore, examples being they have helped us advance wind turbine technology. They have helped the industry overcome market barriers to increase the output of individual turbines and windfarms, to improve the reliability that I mentioned earlier, and to help reduce the cost, all for the onshore side.

For offshore wind energy as well they've been helping us drive down the cost of offshore wind, addressing installation challenges, helping to mitigate the environmental challenges, helping us with grid interconnection and integration, and working supply chain.

Now, I'd like to also importantly talk about the role of DOE in early-, mid-stage, and late-stage research because of the unique ca-

pabilities that DOE has and the unique role that DOE can play. And let me give three different examples. First, DOE has data sets. They've got modeling capabilities, and they have supercomputing capabilities that industry simply does not have. With those types of assets, they have been quite helpful in having us optimize turbine designs.

They've been quite helpful in coming up with algorithms for laying out windfarms to optimize the amount of energy you get out of a single windfarm, and they've also been quite helpful using the supercomputing capabilities to come up with operational algorithms, again, to optimize the output of a windfarm. These are activities the industry simply cannot do because we simply do not have those supercomputers, the modeling capabilities, and the data sets that DOE uniquely does have.

Another role that they can play because of their unique capabilities is as a convener of collaborative efforts. So one example is they have been quite helpful with wildlife detection and deterrence technologies that, because of their colleagues over in the Fish and Wildlife Service care deeply about the impact on wildlife, DOE can play an important convener role that has credibility back with their colleagues at the Fish and Wildlife Service. They've been helpful there.

They've been helpful convening efforts for hardware and software capabilities to mitigate the impact on radar that the Department of Defense cares deeply about or that the Weather Service cares deeply about. So here again, DOE has played a convener and a collaborative role that uniquely DOE can play.

And last, they've been very effective in third-party research that State and local regulators have appreciated. Last, they've also worked well with their colleagues on transmission and grid interconnection.

So, in closing, we fully support the role of DOE and appreciate the opportunity to testify today and look forward to answering your questions.

[The prepared statement of Mr. Kiernan follows:]



House Science Committee, Subcommittee on Energy
Advancing the Next Generation of Solar and Wind Energy Technologies
 May 15, 2019

Testimony from Tom Kiernan,
 President and CEO, American Wind Energy Association

Chairman Lamb, Ranking Member Weber, Members of the Subcommittee, good morning. It is my privilege to be here this morning on behalf of the 114,000 men and women in the U.S. wind industry to discuss the tremendous contributions our industry is making and the important R&D work that is keeping the U.S. competitive. As the President and CEO of the American Wind Energy Association, I am proud to represent our 1,000 member companies with a common interest in encouraging the expansion of wind energy resources in the United States, including wind turbine manufacturers, component suppliers, project developers, project owners and operators, financiers, researchers, utilities, marketers, customers, and their advocates. Today wind energy is lowering the cost of electricity for consumers, enhancing rural economies and actively reducing U.S. emissions. Wind energy is an American success story, providing jobs, investment, manufacturing and related economic and environmental benefits across the country. A few highlights:

- Today a record 114,000 Americans spread across all 50 states have jobs supporting the wind industry.
- Over 500 American factories in 42 states build many of the 8,000 parts found in a modern wind turbine.
- The industry is proud to hire America's veterans at a rate 72 percent higher than the national average.
- At least 69 percent of U.S. congressional districts have either an operating wind farm or wind-related factory, or both.
- The U.S. now has 96,443 MW of installed wind capacity, with wind supplying 6.5 percent of the country's electricity.
- At the state level, six states generate at least 20 percent of their electricity from wind turbines on an average day.
- In 2018, the U.S. wind industry invested \$12 billion in new projects and provided over \$1 billion in payments to state and local governments and landowners.
- The 3,123 new turbines built across 20 states in 2018 are reaching previously unseen levels of productivity. Wind farms built over the last five years have seen average annual capacity factors of 40 percent, with some individual projects in more recent years achieving over 50 percent.
- At the end of 2018, the U.S. had a potential offshore wind pipeline of over 25,700 MW spanning 10 states in the Northeast, Mid-Atlantic and Great Lakes regions.

Now, let me talk about how the Department of Energy's Wind Energy Technologies Office plays an important role in this success story. Spurred in part by the DOE's Wind Energy Technology Office, U.S. wind deployment has more than tripled over the last decade. Today wind is the largest source of renewable generating capacity in the country. The R&D, innovation and collaboration undertaken by the Wind Energy Technology Office has



advanced wind turbine technology and overcome market barriers that would otherwise constrain wind energy deployment. Investments have increased output, improved reliability, and reduced costs. However, continued progress in all these areas will be critical for the U.S. to attain global leadership in wind energy and maximize benefits for the U.S. economy and electricity consumers.

Consistent with other DOE technology programs for nuclear energy, fossil energy and others, DOE has a central role to play in R&D even for a commercial technology like wind energy. For example, DOE's datasets, modeling and supercomputing capabilities are unique and important for a variety of R&D initiatives. DOE's investments and capabilities have enabled higher-risk, higher-reward research projects and analysis that companies could not do on their own, facilitated industry collaboration to resolve tough technical challenges, and provided third-party research results that are often more credible to federal, state and local regulators, thus potentially streamlining permitting barriers.

Over the last several years, the DOE Wind Energy Technology Office has provided support to projects with ties to every U.S. state, helping grow the economic benefits of wind energy across the country. I would like to highlight a handful of the programs undertaken by the Wind Energy Technology Office that continue to play a crucial role in keeping the U.S. on the cutting edge of innovation and clean energy deployment.

Wildlife and Radar issues

The wind industry invests millions of dollars a year and collaborates with federal and state officials and conservation organizations to study the interactions between wind energy and wildlife and to reduce impacts. Continued DOE investments in this area may lead to minimization measures, including detection, deterrent and operational adjustments and/or mitigation solutions that facilitate improved permitting by federal agencies like U.S. Fish and Wildlife Service. DOE can be particularly valuable in helping validate technologies developed by the private sector. Third party validation along these lines can be helpful in convincing federal and state regulators to accept the results and support usage of the solution.

The wind industry also supports continued investment by DOE and partner agencies to test hardware and software solutions to mitigate potential impacts from wind turbines on radars.

Transmission and grid integration

On a larger scale, DOE modeling and analysis has been important in demonstrating how the increasing diversification of generating resources (natural gas, wind, solar, storage etc.) can be reliably integrated into the grid. Continued DOE efforts via the widely-respected experts at the national labs to assess the impact of generation shifts, including even larger percentage of wind penetrations, and recommend approaches to maintaining reliability is valuable for grid operators, utilities, generators, regulators, and consumers.

By way of example, the national labs can help the North American Electric Reliability Corporation (NERC) research how to maintain system inertia with increasing penetration of



inverter-based resources. The multi-lab, multi-technology office “Beyond LCOE” initiative will help consider how to value services the grid needs to remain reliable. And, DOE should invest in regional cost-benefit analysis on various advanced transmission technologies that can help get more capacity and flexibility out of the existing grid and on opportunities to reduce barriers (“seams”) between regional grid operators.

At the regional level, DOE work to improve the coupling of visualization displays with forecasting tools help grid operators better manage their power system operations, including improved outage management and reduced curtailment, so they can utilize wind power at a lower cost.

As part of a wind farm, storage in tandem with energy management software can be used to improve the dispatchability of wind. It would be particularly helpful if DOE were to cost-share the demonstration of long duration storage systems paired with wind, with the goal of validating various energy storage system hybrid designs. The validation would include, but not be limited to, the compilation and reporting of data on changes to ramp control; frequency regulation; and load shaping (over periods of up to one hour). Examples of storage technologies that could be paired with wind projects include flow batteries, steady-state batteries, liquid air energy storage, compressed air energy storage and pumped hydro.

A2e initiative [Atmosphere to Electrons]

This DOE initiative (which involves public-private partnerships) seeks to research, analyze, and validate the aerodynamic effects of complex atmospheric conditions, variable terrain, and machine wakes. DOE datasets and supercomputing power are central to this effort. It is a large challenge that will be a critical element of enabling the industry address imperfect predictions and better optimize turbine design, farm layout, and operation. These improvements will help reduce the cost of energy for both land-based and offshore wind, benefitting consumers.

Advanced technology and components

Breakthroughs and advancements are needed to continue driving down the cost of wind power and other generating technologies. Funding by the DOE enables industry to pursue higher risk/higher reward technology programs that might not otherwise move forward. This area includes investments to analyze and improve component technologies such as towers, blades, drive trains, control systems, as well as material developments.

One area that is of interest to industry is service life extension. The expected lifespan of wind farms has been extended from 20 years to 30 or more years. DOE has played an important role in collaborating with industry to better understand key component failures and strategies to address. Better understandings mechanical component failures can improve the ability to deploy preventative maintenance to avoid problems, prolonging asset life and lowering costs.

Advanced manufacturing technologies

Investments in this area are needed to bring the benefits of manufacturing advances to the wind industry where many suppliers to the major manufacturers do not have the ability to



invest in such advancements. Much of this activity falls under DOE's Advanced Manufacturing Office. Such support can benefit the 500 manufacturing facilities across the U.S. that serve the U.S. wind industry.

Technologies and issues unique to offshore wind

DOE's efforts on research specific to wind turbines in a marine environment should continue focusing on driving down the cost of offshore wind, installation challenges, mitigation of environmental impacts to facilitate federal permitting, grid interconnection and integration, and supply chain needs, all of which are important to growing the nascent offshore wind industry in the U.S.

I am confident that clear authorization and robust funding from Congress will allow the Wind Energy Technologies Office to continue to accelerate innovations and outcomes. We fully support the Office's stated goal of achieving "breakthroughs in reducing the levelized cost of energy (LCOE) for land-based wind by 50 percent from today's LCOE, to \$.023/kWh without subsidies by 2030 and achieving a 50 percent reduction in offshore wind and distributed wind by 2030 from a 2015 benchmark." A cleaner, more diversified, low-cost electricity mix is good for all Americans. Thank you for the opportunity to advocate on behalf of our American wind energy workers for R&D that will keep the U.S. on the cutting edge of wind energy technology.

Tom Kiernan

Tom Kiernan began as CEO of the American Wind Energy Association on May 28, 2013.

Kiernan, a native and long-time resident of Arlington, VA, graduated from Dartmouth College in 1981 with a degree in Environmental Computer Modeling. He began his career with the Nantahala and Rocky Mountain Outdoor Centers, and in 1984, joined Arthur Andersen & Co. as a Management Consultant. Tom left the firm after three years to pursue his MBA at Stanford Graduate School of Business. While at Stanford, he also served as Assistant to the Director of Oregon's Department of Environmental Quality.

Upon completing his degree, Kiernan moved to Washington, D.C., to join the Environmental Protection Agency as Special Assistant to the Assistant Administrator. A year later, he was promoted to Chief of Staff of the Office of Air and Radiation, and then in 1991 was appointed Deputy Assistant Administrator.

At the conclusion of the Bush Administration, Kiernan co-founded the environmental consulting firm E3 Ventures. In 1994, he was hired as Executive Vice President and a year later was named President of the Audubon Society of New Hampshire.

From 1998 until 2013, Kiernan was President of National Parks Conservation Association.

Chairman LAMB. Thank you, sir. We will now begin with questions, and I recognize myself for 5 minutes.

Mr. Kiernan, I was wondering if you could expound a little bit on the supercomputing and algorithmic side of what DOE brings to the table. Do you see that as leading to an achievable gain or accomplishment within the next 5 or 10 years? And I ask that because in my own part of the country we have DOE's main fossil lab there, and they're doing a lot on supercomputing and trying to optimize materials, liquid flows when it comes to hydraulic fracturing, natural gas, and that kind of thing. And I would imagine it's the same out at NREL and other places. And it just sort of seems like we're in this era where a big jump in computing or an algorithmic advance can be applied to existing technology to achieve a lot of efficiency. Is that what you're hoping for, or is that where you're seeing the potential for that?

Mr. KIERNAN. Yes, we have seen it and are looking for more assistance. And I'm sure Dr. Green can also mention it, but a couple of examples that you've got the individual turbine, but because of DOE's modeling and supercomputing capabilities, understanding the airflow through one turbine and its impact on subsequent turbines in a windfarm is extraordinarily complex. And because of their capability, they've been able to say, hey, actually, there are times when you want to let some of the wind slip past that first turbine to maximize output from the second- and third-level turbines and that in total the windfarm, if you think about it as an entire system, is able to increase the output at no additional cost. It's just more intelligently managing individual wind turbines so that the total farm does better. Their Atmosphere to Electrons program and other similar programs at DOE have helped us optimize that management. And yes, we're looking for additional guidance and algorithms to do more so in the future.

Chairman LAMB. And do you believe that some of those advances were actually due to the hardware of the supercomputer that we have at DOE that is not commercially available?

Mr. KIERNAN. That's my understanding, that their capability and their modeling has played a key role in that advancement for the industry.

Chairman LAMB. Thank you. Ms. Hopper, did you have anything to add there as it applies to solar?

Ms. HOPPER. I would—so I was shaking my head on the placement of wind turbines because, as you mentioned, I am very familiar with offshore wind as well, so I appreciate the work that's happened on the wind side. On the solar side, I think they have similar kind of advances in terms of using that—the ability of DOE to—you know, for us it's sort of how you lay out systems and sort of what the efficiency of those systems are. All land is not the same, all roofs are not the same, and so how do we make it the most efficient? And the National Labs have a unique capability that does not exist in the private sector to do that analysis.

Chairman LAMB. OK. Dr. Green, did you see that in your time at Sandia or did you ever encounter some of those supercomputing resources being useful to your work?

Dr. GREEN. Yes, absolutely. The National Labs have enormous high-performance computing capabilities, Sandia, Oak Ridge, and

certainly NREL in the energy space; everything that's said is actually quite, quite accurate. We do rely on these kinds of models for guidance.

Chairman LAMB. OK. Yes, I mean, that to me is—it's an important point because, you know, again, we are—we're doing this in the face of very intense international competition, and we have a ticking clock when it comes to the environment. At least we believe that we only have a certain period of time to solve this problem of climate change. So I think putting these resources from the government and private sector together rather than sort of pitting them against each other might help us within that timeframe.

Mr. Kiernan, I noticed in your written testimony you talked about the wind energy industry hiring veterans at a much higher rate than the national average. Are you aware of specific programs that have helped produce that result or are they just more naturally drawn to the industry? What have you seen?

Mr. KIERNAN. It's a combination of factors. In some cases it's an individual company that, yes, has an effort to outreach to veteran communities through veteran organizations. I think there's also an inherent connection. The men and women that are vets that have the skills to be outside, problem-solving, addressing some key challenges on their own or in teams are often attracted, too and extraordinary employees whether it's up-tower in a turbine addressing some of the electrical or engineering issues. So it's a great fit. They also—frankly, the transition from the mission of serving the country to the mission of serving the country through wind energy is an obvious connection, so it's something that we are encouraging and exploring on how to build some further initiatives industry-wide.

Chairman LAMB. Thank you for those efforts. I'm out of time, and I recognize Mr. Weber for 5 minutes.

Mr. WEBER. Thank you, sir.

Dr. Green, I really appreciate your testimony on innovative research taking place at NREL, particularly in the areas that could be gamechangers for renewable energy technologies like advanced computing that the Chairman mentioned and materials development. But when you look at the budget and compare EERE and NREL, our lead renewable energy lab received \$315 million in FY 2019 or about only 13 percent of EERE's budget. In contrast, DOE's nuclear energy lab, Idaho National Lab, received \$924 million or 69 percent of the Office of Nuclear Energy's total.

If your lab received a larger percentage of EERE's total budget which, as we've noted, is by far the largest of the applied energy programs at DOE, what other types of innovative research could you undertake? Are there currently any areas of fundamental or early stage? You've been chatting with the Chairman about that. Elaborate some more on that for us. What are some things you could do—I'll give you more time on that—that you can't do due to funding restraints right now?

Dr. GREEN. I would say currently, for the examples that I gave, such as solar, more forward-looking research, as well as investigating more advanced technologies to understand how to further improve the efficiencies and the performances. That's one area. The science of reliability, when you have these modules out there for

years to understand and predict how they're going to perform; that's going to be increasingly important.

Mr. WEBER. Are you able to model the wind blade—

Dr. GREEN. Yes, we absolutely can do that. We're able to model and visualize these kinds of calculations provide guidance for experimentalists to work on.

With regard to wind, those new challenges are daunting because, as you pointed out, you're looking at towers, an entire spine going 250 meters. We need to better understand the atmosphere and its interactions with the atmosphere at that level. This problem requires a major, highly collaborative, effort that we'll have to solve.

Trying to optimize a windfarm performance is actually a grand challenge, as it turns out, and it's a grand computing challenge, as well, and we are going to have to begin to validate what we predict.

Mr. WEBER. Are you able to model that—of course, Texas, on the west side of Texas, the western plains we call it has a lot of windfarms out there—

Dr. GREEN. Yes, absolutely.

Mr. WEBER [continuing]. Talking about off the coast as well. Are you able to model the difference between onshore turbines and offshore turbines?

Dr. GREEN. So, yes we have very good ideas. Currently, most of the work is being done on onshore turbines; this is a huge collaborative effort between us, Sandia, Oak Ridge, and all the National Labs, and academia. For the offshore wind turbines, there's work beginning in that area. They pose very different and more difficult challenges; they're all, on-average, larger, they tend to be larger. They tend to be floating, and untethered by a range of things, and they experience much more extreme forms of weather and things like that.

There's a bit more work to be done here, a lot more work to be done.

Mr. WEBER. Well, let me do a follow up to Mr. Stein over here.

Mr. Stein, in your opinion, wouldn't it be a better investment of tax dollars, I appreciate you taking a look at the draft legislation, but wouldn't it be better in your opinion for investment of tax dollars to focus on the kind of fundamental research we see at the National Labs instead of individual grants to companies?

Mr. STEIN. Sure. I think that's the fundamental argument I was trying to make, and some of the things that were mentioned in Dr. Green's testimony sound like things like how to manufacture a wind blade that can be moved, you know, and pieces that can be moved on a road. That's a manufacturing challenge that's really the responsibility of the industry rather than the government to come up with the technical corrections to be able to manufacture and install some of those things.

So I think it's—certainly some of the things that Dr. Green is talking about make perfect sense to be part of NREL's portfolio, but I think some of the—

Mr. WEBER. But be careful about where it goes—

Mr. STEIN. Right.

Mr. WEBER [continuing]. Because in the end you mentioned it could wind up actually limiting what private companies are willing and ready to do?

Mr. STEIN. Exactly. If these companies end up trying to meet benchmarks for materials or wind turbine height or whatever that are set by the Federal Government, they focus on those benchmarks rather than thinking, you know, is there a different way to do this, is there a different location for this, those sorts of things. That sort of innovation—

Mr. WEBER. Right.

Mr. STEIN [continuing]. That—

Mr. WEBER. Well, I appreciate that. And, Ms. Hopper, I want to come over to you. As a former air-conditioning contractor, I paid very close attention to the cost of energy and what air-conditioners drew or the more efficient units didn't draw. You mentioned in your testimony that part of the problem was in the permitting and all of the things that went with getting lined up. I think you said it can save as much as \$1 per watt in soft costs. That's fairly high when you figure a lightbulb is 100 watts, OK? So I think you might want to go back and look at that. It's maybe not as high as \$1 a watt. A single lightbulb, an incandescent light bulb can be more—40 watts, 75 watts. Maybe \$1 a kilowatt?

Ms. HOPPER. I will certainly go back and look at that, but—

Mr. WEBER. Yes.

Ms. HOPPER [continuing]. I'm fairly confident that that's the right number. But we'll go back and look at it, sir.

Mr. WEBER. OK. Just curious. I appreciate you. Mr. Chairman, I yield back.

Chairman LAMB. I recognize Mr. Casten for 5 minutes.

Mr. CASTEN. Thank you, Chairman. Thank you to the panel, and I can assure you that I have sometimes paid \$1 a watt in development costs. Those numbers are—they are shocking and they are high. It's \$1,000 a kilowatt. So, to the panel, I would vouch on that.

I want to talk a little bit about some cross-cutting energy technologies and specifically energy storage. The—growing the capacity for storage on the grid is increasingly critical with the rise of intermittent resources and non-dispatchable resources and is going to be a critical part of the way that we make sure that the lights stay on in the absence of deploying really inefficient fossil generation on the margin that's bad for the environment and bad for the economy.

Dr. Green, in your testimony you discussed the importance of developing diverse technology solutions for meeting our energy storage needs. Can you elaborate for us on why having a wide array of different energy storage technologies is important?

Dr. GREEN. Yes, most certainly. So one of the characteristics of wind and solar is they're variable, for example, you don't have the sun at night. So one of the things we like to be able to do is to predict when they will generate an enormous amount of energy. We would like to be able to store it and use it at a later time. That's one of the primary reasons.

There are in fact a number of methods for storage; of course lithium-ion being the most common one. Certainly you've got pumped hydro, compressed air. And there are a range of other battery technologies out there that people are researching.

Mr. CASTEN. Thank you. Ms. Hopper and Mr. Kiernan, in both of your testimonies you indicated the need for R&D in the later-

stage technologies and field demonstrations, including in grid storage. Can you talk a little bit about what support is—what specific support is needed for later-stage demonstration projects?

Ms. HOPPER. Sure, I will share. I would echo Dr. Green's sentiment that rapid deployment and broad deployment of storage is critical to reaching high penetration levels for renewables, as you know, Congressman. And so I think the most important thing for the demonstration project is to demonstrate to utilities, who are actually the ones who have to operate the grid, that this storage capacity can—is operable. It can interact, and it certainly can interact at large scale and that the—these intermittent resources, wind and solar being the two most important ones, can function and provide reliable power. So I think the Federal Government has a unique role to play in proving that out.

One of the things we haven't really—we've sort of assumed but haven't said explicitly is that NREL and all of our National Labs have a—they are respected, they are—they have a unique role in verifying, sort of, systems and verifying technologies that the private sector doesn't have. And so as we look to utilities to adopt these technologies, if they have been verified by something—by an institution like NREL, they're going to have much broader adoption.

Mr. Kiernan?

Mr. KIERNAN. Two quick things to add. First, in looking at storage, I agree it's important on the grid and that we need to look at multiple types of storage, not just batteries but pumped hydro, other technologies that allow you to store energy for long periods of time is very helpful for the grid, one point.

Second is I would encourage the Committee also to think about transmission. Transmission is critically important to enhancing the grid and to enabling more wind and solar from remote places where it's generated to have the transmission grid to move it to load. That's not storage, but you can think of it as storage in that you're bringing new energy from one distant place to load where it's needed when it's needed. So, as you're looking at an infrastructure bill, potential bill, please look seriously at transmission and enhancing the grid through that.

Mr. CASTEN. The follow up for both of you, you know, I think all of us who have spent time in the energy development space are aware of this valley of death where the risk is still a little bit too high for the private sector, but, you know, it gets hard to push back on people who say government shouldn't be there anymore. Can you speak specifically to what you would like to see the National Labs doing to help de-risk those storage technologies that are close but not quite to the point where the private sector is taking them up yet?

Ms. HOPPER. Thank you for that question. Yes, I think across sectors people are very familiar with the valley of death. And as I think about solar companies and storage companies, there's about—you know, we've talked—we have about 10,000 solar companies specifically. About 3 percent of them have more than 500 employees. The vast majority of those are small businesses. So as they look at sort of their resources to commercialize some of these

technologies, they just aren't there. So this—I think it's a false assumption to say that the private sector will simply take over.

So what do I think the National Labs need to do? They need to move through that stage of development. They've done the basic research on sort of what the options are, and then do more research to work toward commercialization. And I think they are uniquely positioned to do that. It's not a place the private sector is going to take over. And I do believe it's for the public good as we think about how we are transforming our electric grid and what we want that energy portfolio to look like, it is because it's going to benefit American—the American public, and so there's certainly a public interest in making that investment.

Mr. KIERNAN. The only quick thing I would add, if I may, we are very, very early on in figuring out hybrid projects, projects that have wind and solar and storage as one that allows the developer to provide quite stable electricity to customers. There was a reason—one of the few examples, but Portland's gas and electric provided by NextEra, and there's a whole lot of additional research that can be done, needs to be done to figure out how you create these hybrid wind-solar storage combined projects to help the grid.

Mr. CASTEN. Thank you, and I yield back my time.

Chairman LAMB. I recognize Mr. Biggs for 5 minutes.

Mr. BIGGS. Thank you, Mr. Chairman. I appreciate the Chairman and the Ranking Member for holding this hearing today. I thank each of the witnesses for being here.

As I think some of you, particularly Ms. Hopper, noted, Arizona with regard to solar is highly developed I guess I would say compared to many of our friends, other States around the country. And people just naturally assume because Arizona gets 361 days of sunshine a year, we're going to be the leader. But we're not number one yet, but we certainly are making advances.

But I wanted to talk a little bit; I've enjoyed listening to each of you testify today. Dr. Green said at one point that windfarms are underperforming. I don't disagree, and my research kind of indicates that as well.

And I appreciate, Ms. Hopper, talking about regulatory reform necessary, and I'll roll that back into what I'm going to say in just a second, and then Mr. Kiernan talked about transmission and all of you have talked about storage, Mr. Stein, others talked about storage. That is really critical if this is going to succeed in the long term.

But I want to talk about something that's important to my home State with relationship to both solar and wind, and that is the notion of the necessity for critical minerals that go into the creation of solar panels or infrastructure in facilities for either types of solar windfarms. So it is important that we streamline mineral development in the United States. This is to sustain production and the infrastructure necessary to deliver energy, whether it's these green energy or traditional energy. Solar industries, for instance, are dependent on minerals, including aluminum, cadmium, gallium, indium, iron, lead, nickel, silica, silver, tellurium, tin, zinc, and copper.

And I bring up mining because over the last 20 years the U.S. has doubled its import reliance to the point that we are now 100

percent dependent on foreign countries like China and Russia for 20 metals and minerals, many of which are essential for energy infrastructure, national security, and defense application. The President and his Administration have published executive directives to begin important work on identifying immediate domestic sources for critical minerals, including the need for geophysical mapping of the United States to support management of private-sector mineral exploration and to provide data for land-use planning.

Still, a lot of our friends on the other side of the aisle are pushing anti-mining legislation, including the friend of mine from Arizona, who is the Chairman of the National Resources Committee. That will crush the hard rock mining industry, impose punitive high royalties, a new dirt tax, and add more red tape to the permitting process.

These minerals are critical to the future of what you do and what you want to see happen, and just like you would like to see regulatory streamlining done in your particular fields, it seems to me that we should be looking at that with regard to mining. Right now, we have a copper mine that has been waiting to go online for 15 years and has spent \$2 billion and has not been able to turn a spade of dirt yet, \$2 billion. So this is critical.

And also we need to recognize that there are potential environmental costs as well. Clearing land for solar energy infrastructure may have long-term effects on habitat for native plants and animals. Even in the pristine, secluded deserts of Arizona where I'm seeing solar farms go in, there was a necessity for water as well, which is, in the desert area, can be very tough to get to. And in Arizona only 4.6 percent of our source of energy comes from solar energy.

But it's home to nuclear. Three nuclear power reactors have produced almost 30 percent of Arizona's electricity while emitting no greenhouse gases. Additionally, the Palo Verde Nuclear Generating Station is America's largest and employs more than 2,500 workers.

The private sector, which is better equipped than the Federal Government to research and develop renewable energy technologies generally, is already leading the way in advancing solar and wind energy technologies. For instance, APS announced a major clean-energy initiative, including new battery storage, which I think you all talked about, and I think that's critical for the success of green energy in the future. And they intend to build additional new solar plants with storage that will deliver affordable energy to Arizonans. This initiative will add 850 megawatts of battery storage, more than 100 megawatts of new solar generation. And Secretary Perry called this a "great example of an all-of-the-above approach to energy policy."

In short, I think nuclear energy is also a reliable source of electricity in the United States. I appreciate each one of you and your work and your effort, and with that, Mr. Chairman, I yield back.

Chairman LAMB. Thank you, sir. Ms. Horn recognized for 5 minutes.

Ms. HORN. Thank you, Mr. Chairman. And thank you all for being here and for your testimony today.

I live in a district—I'm from Oklahoma. I live in a district with a strong presence of hydrocarbon, natural gas, wind, and solar, so

we have a lot of energy in Oklahoma, as you might imagine. And, Mr. Kiernan, in your written testimony you said that DOE modeling and analysis has been important in demonstrating how the increasing diversification of generating resources—natural gas, wind, solar, storage, all of the above—can be reliably integrated into the grid. Can you elaborate a little bit more on the importance of diversification of energy sources and what it looks like in terms of reliability and stabilization as we move forward?

Mr. KIERNAN. Did you want that for Mr. Green or for me, Mr. Kiernan?

Ms. HORN. Oh, Mr. Green, I'm sorry. I—wrong person. You were nodding, and I—Mr. Green, that's for you.

Dr. GREEN. I think the diversification of the energy generation sources is actually very important, and it's happening right now, particularly as we go through the energy transition; we must combine renewables with the conventional sources. There are lots of unknown questions. And one of the major activities in which NREL is currently engaged is a proposal for what we call the Flatirons Campus, where we were going to have megawatt-type solar arrays, wind, natural gas, a range of sources. Here we're going to begin to understand essentially how we can look at the performance of hybrid systems, for example, combined storage and energy generation, and how would these perform in relation to generation from fossil or even from natural gas.

This new campus has a series of assets, as I mentioned, that includes solar and wind. We have high-speed connections to Idaho National Lab, with nuclear energy. And so this is going to be a unique facility which really will enable us to understand how the new grid of the future is going to operate, at some level.

Ms. HORN. Thank you. And many of our energy companies now are finding innovative ways to reduce water usage, increase efficiency, and use technology to help get us to cleaner energy, reducing emissions. But we know that these transitions from our current systems to what comes next from fossil fuels to natural gas to the next generation is costly, and it takes time.

And we've heard about, you know, ambitious timelines, which, quite frankly, I'm a little bit concerned about given the cost and the—where the technology is. So I think I want to be—my question is how do we get—be realistic about this tradeoff, what it's going to take to encourage this transition to get there sustainably and in a way that doesn't hurt jobs in the process but that sustains us—hurt jobs raise cost to consumers—in a sustainable way? And I'll leave that to—if you want to take it or if anybody else, whoever wants to take that one.

Dr. GREEN. I'll give one answer and then the others can join me. What's happening is that we're progressing in a natural way, we can define goals for the next few years in such a way that are achievable long-term, and are quite sustainable, and that's really what's happening right now.

Ms. HOPPER. Sure. So thank you for that question. I agree that ensuring that consumers have access to low-cost, reliable, affordable energy is critically important, and I think the only way that this transition will happen is if the sectors that we represent, wind and solar, can offer that. And I think what we have talked about

is that over the last decade those—the cost of solar specifically—and Tom can talk about wind—have fallen dramatically so that we are the lowest-cost option in many cases. And we talked about storage to provide that 24/7 reliability, and so I think that transition can happen and certainly will be enhanced by continued investment in R&D.

Mr. KIERNAN. The only thing I would add, we support having multiple sources of generation on the grid. It is that diversity and the diversity of attributes and capabilities of wind versus solar versus gas versus—that enable a very stable grid, pulling those together. And what I know wind is looking for going forward is the ability—and we’re talking to FERC (Federal Energy Regulatory Commission) and the RTOs (regional transmission organizations) about this—the ability to compete in providing both the electrons but also the reliability services, voltage support, frequency support that actually wind is uniquely capable of providing. We want a market out there so that we can compete in providing those services and, over time, different sources can take on greater amounts of work on the grid.

Ms. HORN. Thank you. I—my time is expired. I yield back.

Chairman LAMB. Thank you. I recognize Mr. Babin for 5 minutes.

Mr. BABIN. Thank you, Mr. Chairman. I appreciate it.

Mr. Stein, I love the example that you use of how government funding for NASA’s solar space application led to the solar technologies that are now being applied to electricity generation. As the Ranking Member of the Space Subcommittee, I think that NASA is one of our most valuable research entities, so I want to thank you for recognizing that.

But I think you’re right when you say that we should only be funding research to create the foundation of new technologies, not using tax dollars for the whole lifecycle to commercialization. Is there a different area of solar or wind, something revolutionary or market-changing that would be a better recipient of our limited Federal moneys for research?

Mr. STEIN. Well, one example—I mentioned it briefly, and Dr. Green also I think mentioned it is research into perovskite materials in solar cells. These are different—these are new materials that aren’t currently used in solar cells, and they have shown a lot of promise for being very efficient, using—you know, using less resources per watt developed, so—

Mr. BABIN. Yes.

Mr. STEIN [continuing]. I think that’s—I think that’s a perfect example of—and that’s something that NREL is already doing and—but my point also is that once you’ve got that foundation, that discovery, the actual application, finding where it works best, what sort of applications, that’s really—should be the private sector role rather than NREL.

Mr. BABIN. I got you. And another thing I thought was intriguing when you said, and I agree with you, that Federal support should not go to projects that private interests have already got a clear incentive to develop. Can you give an example of a time that EERE or another program has used Federal funds to develop something that very easily could have been done by the private sector with

no cost to the American taxpayer I might add? Supporters of the Green New Deal want us to completely cut the power on our current energy grid and transition to 100-percent renewables over the next several years, and I see that being detrimental to our economy. And can you explain how a more targeted plan to invest Federal money on early-stage clean energy research followed by private sector development and deployment to better maintain our economic growth and lessen the burden of our working class? I know that was two questions that I—

Mr. STEIN. Yes.

Mr. BABIN [continuing]. That I asked, the first one of course the primary answer I wish you would give first.

Mr. STEIN. Sure.

Mr. BABIN. OK.

Mr. STEIN. Well, the famous example is—goes back to the stimulus and some of the money that was wasted on that. Obviously, Solyndra is the famous example—

Mr. BABIN. Right.

Mr. STEIN [continuing]. Where you had a private company that was—already had a manufacturing technique that they were trying to develop, and the Federal Government basically wrote them a blank check. The problem was is that they weren't really ready for primetime, and that's part of why they were struggling to get private funding in the private market.

So I think that's an example of when you look at the—the SEIA, she earlier mentioned that it's a lot of these smaller businesses that's the solar industry, but the large utilities are also making these investments. There's other parts of the private sector there making investments into rolling out—they've made a lot of commitments for certain percentages to come from renewables in the future, that sort of thing. And those are private-sector commitments, and some of those are driven by State-level governments. But the point being is that that's a private groundswell of both consumer demand and regulatory demand.

Mr. BABIN. Right.

Mr. STEIN. It's not the Federal Government setting those benchmarks and trying to force the private sector to meet them.

Mr. BABIN. OK. Thank you very much, and I yield back, Mr. Chairman.

Chairman LAMB. Thank you. Dr. Foster for 5 minutes.

Mr. FOSTER. Thank you, Mr. Chairman. Thank you to our witnesses.

Previous questions have emphasized the crucial nature of energy storage to high penetration of wind. And this is something I've agreed with for a long time. And it's one of the reasons I plan to reintroduce the *BEST Act*, the *Better Energy Storage Technology Act*, that expands grid storage R&D, as well as demonstration projects. And it also directs DOE to establish cost targets for energy storage, which I think are going to be crucial for just benchmarking progress.

And so my question is, what do you see is the balance between R&D needed for energy storage and demonstration projects that would just have the utilities gain confidence? Dr. Green?

Dr. GREEN. Yes, I agree there is significant research that needs to be done; just consider lithium-ion batteries for example, one of the challenges is it has cobalt, which is limited in supply, and the idea then is you're going to have to find new electrodes that perhaps are cobalt-free—

Mr. FOSTER. Sure, well, the JCESR (Joint Center for Energy Storage Research) Program at Argonne, they're very—the—

Dr. GREEN. Right, as just one example.

Mr. FOSTER. Right.

Dr. GREEN. There is research that needs to be done on a range of other battery chemistries, for example, sodium-ion batteries that perhaps may be more safe for long-term use and more sustainable.

Mr. FOSTER. And now in areas like pumped hydro. I've been really impressed at how mature the technology came almost immediately, I don't know, by 1920 or 1930—

Dr. GREEN. Right.

Mr. FOSTER [continuing]. Essentially everything had been already optimized.

Dr. GREEN. I wouldn't say it's already optimized, but it's certainly the most commonly used one, but it's only available in certain parts of the country.

Mr. FOSTER. And so is the—is—well, maybe, I'll switch to Mr. Kiernan. You emphasize the importance of distribution network, and, you know, there are many concepts of this. There's, I guess, high-voltage DC overlays across the whole grid, you know, more speculative things like superconducting power transmission lines, which are actually, I believe, now being deployed at some scale. And so, again, what is the mixture of effort that you think would be optimum here, you know, technology development, system modeling in cases where things like high-voltage DC lines, the main problem is that no one wants NIMBY (not in my back yard)—to see new high-voltage lines and so the best response there would be robotic underground installation to drop costs. Where do you see the best bang for the buck both in R&D and demonstration?

Mr. KIERNAN. Let me share a big picture—in agreement, there are multiple enhancements to the grid with transmission that we are looking for. Yes, long-distance DC lines would be helpful and cost-effective I'll point out. As well, though, there are some shorter transmission lines that connect the seams on the grid. You have different grids throughout the country, and they don't often connect well between the different grids, so actually getting the different RTOs, the different grid operators to plan together where they might collectively build transmission lines across these seams between the different grids is also a really important way to advance the grid. So we've been encouraging Congress, as you're looking at your infrastructure bill and potential transmission enhancements, guidance that you can give to FERC to encourage the RTOs to do simultaneous planning or planning together is one way. Also different ways of giving FERC some type of backstop siting authority limited to encourage States to move the permitting process. Yes, permitting for transmissions difficult and there needs to be some incentives or encouragement, and Congress can be helpful there.

Mr. FOSTER. Now, the seams you refer to have to do with the phase slippage between different sub-grids where you just can't

connect them or that would be presumably solved with a DC overlay?

Mr. KIERNAN. In——

Mr. FOSTER. Or——

Mr. KIERNAN [continuing]. Places that—normally, it's honestly just the seams between two different grids, and we just need more interconnects between the grids so they can move power. For example, up in the Pacific Northwest and then you've got California, having—they're doing some testing and some modeling right now of connecting those grids so that, for example, the Bonneville Power and all the hydroelectricity can move down to California when they need it, and when you've got extrasolar power down in California, it can get shipped up. That energy-imbalanced market that they're creating is proving very cost-effective to consumers, so more transmission lines that connect the grid allow you to save money for consumers because you're getting excess power from one region, moving it to another when they need it, and vice versa.

Mr. FOSTER. So the difficulty is the energy imbalance rather than phase—multicycles of phase slip are sort of a thing of the past is what you're telling me?

Mr. KIERNAN. It is the energy imbalance——

Mr. FOSTER. OK.

Mr. KIERNAN [continuing]. Where we can, with limited transmission, solve or address the problem.

Mr. FOSTER. Thank you. And I'd be interested in specific research areas there that the government might consider investing in.

Mr. KIERNAN. We can offer that——

Mr. FOSTER. My time is up and yield back.

Chairman LAMB. Thank you. Mrs. Fletcher for 5 minutes.

Mrs. FLETCHER. Thank you, Chairman Lamb, and thank you, Ranking Member Weber, for holding this hearing today. Thank you to the witnesses for taking the time to testify.

I am from Texas where we believe in an all-of-the-above energy approach. And many people know, of course, of Texas' long history in producing our Nation's energy, but many people are surprised to hear that Texas is the largest wind energy producer in the country and that we are producing about 25 gigawatts of wind power, as the Committee Chairwoman noted in her comments this morning, and supporting nearly 25,000 jobs in wind energy in the State. We have three times more installed wind capacity than the second-highest-producing State, and in fact, there are only four countries in the world that produce more wind energy than Texas.

Now, this wind energy surge was made possible after then-Governor Rick Perry invested \$7 billion for electrical transmission projects that connected West Texas with its abundance of wind potential to distant metropolitan areas like my own in Houston, which really is distant in Texas, as many of our panelists know with their connection there.

So those new lines drew investments from industry into renewable energy and made us the leader that we are today. So in Texas we believe that there is a mix, there is a mix of different energy sources that's important, and that we believe that the government has a role to play, that industry has a role to play, and that academics and research have an important role to play in bringing all

of these things together. And that's what we want to do is bring everybody together and look at what our energy future looks like.

So I want to touch on a couple of follow ups to some of the questions that were asked today, in particular, Ms. Hopper. Mr. Casten asked you some questions about storage, as did Mr. Foster, and I think storage really is the linchpin to providing reliable power in the solar and wind sectors. And so what I would love is kind of sitting here today, from your perspective, do you have an estimate or a timeframe on what we're looking at for when we will have that reliable power source and more storage? What are kind of the estimates on that right now?

Ms. HOPPER. Sure, thank you for that question. And I just—I just have to say, so Texas is the number-five solar State in the country now, and we think it will be number two in the next 5 years, so I hope that you will consider broadening your perspective and thinking about Texas as not only a wind powerhouse but soon to be a solar powerhouse as well.

Mrs. FLETCHER. Yes, and we do, and I did not mean to skip that. Certainly in Houston we have many of those 10,000 jobs right in my backyard.

Ms. HOPPER. Absolutely. Absolutely. So Mr. Kiernan and I have the pleasure of having a good relationship with our colleague who's the head of the Energy Storage Association. They have—their goal is to have 35 gigawatts of storage deployed by 2025, so pretty short order. That level of deployment I think will be transformational in terms of providing reliable—so our power is reliable today, but in terms of what you're looking for, which is sort of that 24/7 product, I think it will be transformational in providing that. So that's certainly the goal that the storage industry is looking toward, as the Congressman said. Sort of setting those benchmarks is important so that we can measure progress and we can direct our focus and our R&D investment to make that happen.

Mrs. FLETCHER. Great, thanks. And I have a follow-up question. There's one thing that we know as the energy capital of the world in Houston is that it is a global business, and one of my concerns—and I think you all know well—there is strong international competition to develop and commercialize solar and wind technologies. And it's often between the United States, European countries, and China. So could you explain how the DOE-led solar and wind energy R&D allows the United States to remain competitive and improve its economic competitiveness in these markets? Maybe, Dr. Green, can you talk about that for us?

Dr. GREEN. We have remained competitive, and will continue to, provided we remain funded. The funding model where you have this interaction between academia, National Labs, and industry is a very effective one. DOE has, for example, the basic research supported by BES in some areas, together with EERE more to the applied end, this has been effective.

If you look in terms of our scientific infrastructure as a Nation, we still remain the leader and our ability to advance renewable technology is largely based on this very advanced scientific infrastructure.

Mrs. FLETCHER. OK.

Dr. GREEN. And so—yes.

Mrs. FLETCHER. Thank you. I want to get in one quick other question before my time expires. So maybe, Ms. Hopper, could you briefly touch on related issues like the impact of tariffs on imported solar panels that may make it difficult for solar companies to invest in research, development, demonstration, and commercialization activities even when they are facilitated by DOE?

Ms. HOPPER. OK. So thank you for that question. Obviously, the impact of both the solar-specific tariffs as well as the pancake effect of the—I can—just the aluminum tariffs and the other tariffs that have been imposed by this Administration have proved very challenging to our industry. They are additional costs. They're an additional tax to our consumers, and so that has made our product less competitive. The growth that we had anticipated over the last—so 2017, 2018 has been stalled, and so we have flatlined instead of grown, which has been frustrating.

So if you—you know, obviously, I think all of the—many of the research that our companies do do in partnership with the Federal Government requires cost share, right, and so there's—you have less product, less demand for your product, and less—you know, it's more expensive, it's harder to invest in that R&D. And so it has—that has been one of the sort of things we haven't talked about as much, but that has certainly been one of the impacts of tariffs is that there is less opportunity for us to continue to invest in that R&D with the government.

Mrs. FLETCHER. And thank you very much. And thank you, Mr. Chairman, for your indulgence in letting me go over. I yield back my time.

Chairman LAMB. Thank you. Ms. Stevens for 5 minutes.

Ms. STEVENS. Thank you, Mr. Chairman. And thank you to our witnesses.

I represent a district in southeastern Michigan, the suburbs of Detroit, and Michigan has a robust wind and solar energy presence. I was very proud to lead a letter with about 100 of my colleagues signing on with Mr. Paul Tonko to the Chairman of the Ways and Means Committee encouraging the Chairman to call for incentives for clean energy to be included in any tax-infrastructure package that we put forward. We're also thrilled in Michigan that we have Utility Workers Union of America with 10,000 employees who are playing a leading role in this space.

But what I'd like to hone in on today is something that Mr. Stein said and has in his testimony in which he said that mature industries like the wind and solar generation sectors with extensive and dynamic economic activity are not in need of Federal interference, however well-intentioned. Mr. Stein went on to say that, while basic research is a reasonable Federal role, responsibility for later phases of the business cycle such as commercialization or deployment are best left in the hands of the industry itself.

Ms. Hopper, in your testimony you devoted significant time to addressing the soft cost through targeted research and programming.

And, Dr. Green, we're so proud of your work and what NREL represents and what you've been able to accomplish and achieve as a research institute. And what I'd like to do is just ask Ms. Hopper to hone in here so that we can be really clear about what we are

talking about with the role of the Federal Government in commercialization of technologies where we need this convening power. So do you mind, Ms. Hopper, just chiming in a little bit about, without DOE's significant investments in solar energy technology research, where the industry would be?

Ms. HOPPER. So, first of all, thank you for the question and thank you for your leadership on the letter. I think it was a great message to send.

So I'm happy to hone in on that. I think if you're—what I heard you asking me was sort of where would we be if not for the investments that have been made by the Federal Government? And I think we—if we look back to 2010, in 2010 we were at 0.1 gigawatts of solar deployed in the United States. At the end of this year, we'll have over 70 gigawatts, so that's a big increase. I don't know the percentage. It's a huge increase, right, .1 to over 70 gigawatts.

And that happened because costs came down. And costs came down because there was investment at the Federal—by the Federal Government in that basic research, right, in figuring out what are the materials that work. There was investment in the commercialization, sort of what—how do we take those—that basic research and make it so that it is commercially viable, right, at scale and at scope and at price? And then certainly how do we bring people together to solve problems that are really too big for one company to solve? So as I think about that, I think about soft cost. Obviously, I talked about that.

One company is not incented to figure out how the entire—you know, every building inspector in the United States is going to more efficiently inspect solar systems on roofs. One company is not incented to figure out the best way to integrate these different resources regardless of what kind of technology they are into the grid. One company is not incented to figure out cyber—so how do we solve cybersecurity? I mean, we have these—all these different ways that, you know, different entry points into the grid, many more than we're used to, so one company doesn't do that. And so I think our investment pays off in those situations. And storage we've talked about.

And then I think similarly, as we think about sort of the convening power in solving some of these big questions together, the Federal Government is uniquely positioned to do that. And so we would be, I think—you know, I wouldn't be able to say 70 gigawatts. It would be a much, much smaller number at a much higher price.

Ms. STEVENS. Sure. Well, I'll also make note that we had a transition in the House of Representatives on January 3, and we have a new majority. And it's a robust majority, a lot on the docket particularly in terms of, you know, restoring the faith and trust in government, the doing and delivery for our country, and I'm so thrilled to see that our Democratic majority is here today engaging in this discussion in a way that is quite meaningful to the charge of the time, which is how do we capture an economic opportunity as well as address the challenges around energy efficiency and climate change? So kudos to our Chairman for bringing us here today.

With remaining time if we don't mind I've got one more specific question for Dr. Green. Airborne wind technologies, you know, including those developed by a company that was previously supported by ARPA-E and now owned by Google have a lot of immense potential, and they still appear kind of far from this commercialization space. Could you speak to NREL's work with airborne technologies and the potential obstacles and opportunities for further development?

Dr. GREEN. We're not doing very much in the direction of airborne technology. Our work is looking at land-based wind and offshore wind for the most part. At this point we're not looking in great detail to the airborne technologies.

Ms. STEVENS. OK. Do you—does NREL need further support for commercialization activities? If it's not in the airborne space but in other spaces that pertains to wind and solar or do you have what you need at this point?

Dr. GREEN. No, I think what I articulated earlier in terms of the future of wind and the expansion and capacity—well over in order of magnitude from where it is today, there needs to be an enormous investment for us to get there.

Ms. STEVENS. Yes. Well, thank you. I have gone over my time, but I would like to close by applauding Mr. Stein for his support of basic research and applauding our witnesses for their support of research commercialization and leadership in the space of wind and solar.

Thank you, Mr. Chairman. I yield back the remainder of my time.

Chairman LAMB. Thank you. Mr. McNerney for 5 minutes.

Mr. MCNERNEY. Well, I thank the Chairman.

Good morning, and I thank the witnesses for coming this morning. This is exciting. You know, I developed wind energy technology for 20 years before coming to Congress, and I loved doing it.

As we both know or as we all know, the wind—the cost of wind and solar has decreased dramatically. The levelized cost of energy, 88 percent for solar and 69 percent for wind over the last decade. Now, you already got to answer that question, Ms. Hopper, so I'm going to ask Mr. Kiernan. What has driven the reduction in cost of solar, including basic research?

Mr. KIERNAN. You mean for wind, sir?

Mr. MCNERNEY. Wind, wind, yes.

Mr. KIERNAN. A couple of factors. One, it has been the lengthening of the blades. Dr. Green referred to that. That is an important development. It allows us to capture more energy having longer blades. Taller towers and all the digitalization, computer application inside the turbine and the management of the entire windfarm, all of those have been kind of the primary drivers for the dramatic reduction in the cost of wind energy. And I will say, given research that's going on at DOE and in the industry, we are anticipating continued reduction in the cost of wind energy.

Mr. MCNERNEY. Well, I like hearing that. Ms. Hopper, what are the biggest costs in residential solar installations? Do you have a way to answer that?

Ms. HOPPER. Certainly. The largest bucket of costs in residential solar installations are the soft costs, so those, as you know, the per-

mitting, the inspections, and the time that it takes. We think that's about one-third or so of the costs. And those—bringing efficiency to that sector and sort of reliability and predictability to that I think will cause great decrease in the cost of residential solar. And so if—you know, Federal assistance in streamlining that could be incredibly impactful.

Mr. MCNERNEY. So you've sort of already answered this question, but the trade wars that we're now engaging in, is that going to increase the cost to the residential solar customer?

Ms. HOPPER. Yes, that's a good question. So the—just the solar-specific tariffs that were imposed year 1 were 30 percent tariff. We're now in year 2, so that's a 25 percent tariff. That—so that's an increase on the cost of the solar module, which is not the entirety of the project, but it is a significant portion, especially—you know, it's different in each market segment, but it's significant regardless, and so yes, it will—it has and will increase because one of the basic components has increased in cost.

Mr. MCNERNEY. What about cost on American jobs?

Ms. HOPPER. So as we looked—you know, we do a solar—The Solar Foundation does a solar census every year funded in part, I believe, by the Department of Energy, and that showed over the last—I think from 2017 to 2018 we lost about 8,000 jobs in the solar industry. Those are jobs actually lost. What it didn't capture because it's hard to capture are the jobs that were never created, right? So if you went back and looked at what our projections had been prior to the tariffs, we were on an upward trajectory. That—we flattened out and went down, and so I think there is another delta of opportunity not realized that's a little bit more difficult to capture.

Mr. MCNERNEY. Mr. Kiernan?

Mr. KIERNAN. If I can jump in on the wind side that absolutely the tariffs that are in place and being increased will increase the cost of wind energy in this country, harming consumers, increasing the cost of electricity to consumers because some of the important components we are importing, and those tariffs are increasing the cost. We have submitted testimony, and we can get it to you, testimony to the USTR (U.S. Trade Representative) about the particular number of jobs lost and increase in electricity cost to consumers and businesses as a result of these tariffs. It is deeply concerning to the industry.

Mr. MCNERNEY. Thank you. Mr. Green—Dr. Green, I did start my professional career at Sandia National Laboratories, but I spent many years at the National Wind Technology Center as well, windy nights, shaking trailers, and Chinook winds and so on. But somehow this Administration's budget has asked to expand the NWTC's office to better incorporate grid modernization research, including energy storage and diverse electricity generation sources. Why is the NWTC the right place for that?

Dr. GREEN. It's the right place because right now, it has some key assets in addition to the wind machines and the large megawatt solar arrays; it has electrolyzers, a megawatt-sized electrolyzer, and in addition to that it has connections to other energy assets like high-speed connections to Idaho National Labs.

It's going to be a place where people can begin to test and validate a range of new technologies, the hybrid technology I mentioned earlier, storage and generation. It's going to be able to, for example, understand how the new grid is going to deal with faults that exist. Earlier, we heard about trying to control on the voltage and frequency in the grid.

This is the kind of place where we begin to test new technologies to understand how they operate before you take them out to the field. It's going to enable the grid of the future; the grid of the future is going to be an autonomous grid, and the kinds of experiments that are going to be done will be done at the Flatirons; they're going to be unique. There's no other facility in the world can actually do what we propose to do, and so it's very—it is going to enable what's needed for the future in that sense.

Mr. MCNERNEY. Well, thank you. I hope to get out there to visit you guys.

Dr. GREEN. Well, we'd certainly love to see you.

Mr. MCNERNEY. I yield back.

Chairman LAMB. Thank you. And Mr. Tonko for 5 minutes.

Mr. TONKO. Thank you. And I thank you, Chairman Lamb, and Chairman—Chairwoman Johnson for allowing me to wave on and for holding this important hearing on these draft bills. I'm sorry I've had to miss some of the discussion. I was across the hall with a hearing that I'm chairing.

But I've introduced versions of the *Wind Energy R&D Act* since my freshman term, so I'll be focusing on the wind element of today's hearing. Sorry about that, Ms. Hopper. But during that time, the industry has grown significantly. Clearly, these are great opportunities for domestic wind, but we should not pretend that challenges do not still remain.

So, Mr. Kiernan, what are some of the biggest barriers the industry faces to further deployment? And can DOE's wind office help lower those given barriers?

Mr. KIERNAN. We perhaps refer to them as opportunities. We do see significant opportunities to continue reducing the cost, but we do need that primary and late-stage research, whether it's on transmission, as I've mentioned earlier, whether it's further digitization, improving the intelligence if you will of the management of a particular windfarm, integrating all of the different wind turbines on that windfarm, and better integrating wind onto the grid with solar, with storage, and, I mentioned earlier about enhancing the transmission. Designing that grid of the future is a significant opportunity. It's needed, and we are looking to the research capabilities of DOE to lead in that effort.

Mr. TONKO. Thank you. And in 2015 DOE updated its Wind Vision report setting a target of 35 percent of U.S. electricity generation from wind power by 2050. We know that our Nation has excellent wind resources, particularly from Texas to the Dakotas, but DOE and NREL also published a report called "Enabling Wind Power nationwide." This report found that taller towers, larger blades, and more efficient turbines can unlock wind's potential in many other regions, including the Southeast.

So, Mr. Kiernan and Dr. Green, what are some of the challenges to developing taller and more efficient turbines, and can DOE research help?

Mr. KIERNAN. DOE's research is helping. I'll yield to you, Dr. Green, in just a second. Thinking through both, as was mentioned earlier, the atmospheric issues at that higher elevation are extraordinarily complex. We don't have the modeling or the capability to do that. They do. Also, some of the logistics. A tall turbine is tough to get to that site, so thinking through those logistics as equally complex as the longer blades, maybe having segmented blades, so these are challenges that we do look to assistance and leadership from DOE given their unique capabilities industry does not have.

Mr. TONKO. Thank you. Dr. Green?

Dr. GREEN. You characterized it well. I would add one additional thing; it's that as you make these taller and taller towers, they're going to have to be limited in weight and they're going to have to be cheaper and so this means new materials and new processes, and that's where the new research is actually going to happen.

Mr. TONKO. Thank you. And while some may suggest that wind energy is fully mature, I believe there are numerous ways in which there are still nascent aspects of the industry and substantial room for greater innovation. For example, there are emerging issues that must be addressed in order to unlock our Nation's offshore wind potential, including floating platforms in the Pacific, which have not yet been commercialized, as well as distributed wind deployment.

So, Mr. Kiernan, what are some of the ways that industry is hoping to continue to be able to be innovative and to improve technology development, reduce costs, and enhance grid integration?

Mr. KIERNAN. Let me build off of your one example with which I agree, and that is for offshore wind, the floating turbines, which are to date viewed as notably more expensive, but a lot of people think that, as we figure out that—how to do the floating turbines and are able to standardize that process, they may end up actually less expensive than the current kind of monopile attached to the seafloor bed because we can take that to scale. So a good example, having the research for floating turbines may in the long run dramatically both reduce the cost and obviously enable offshore wind to be all over, whether East Coast, West Coast, wherever appropriately sited, we don't have to be only in certain limited depths.

Mr. TONKO. And do you believe that the Wind Vision targets are likely to be achieved without sustained Federal RD&D investments?

Mr. KIERNAN. We need DOE's additional funding to hit the Wind Vision targets. We were involved in the creation of Wind Vision, very much support that vision, do see it as a partnership. The industry is providing—obviously investing \$12, \$13 billion a year in this industry, and we look to the unique capabilities and roles that DOE can play to assist us. Even though, yes, we're providing dramatic private investment, we need them as a partner.

Mr. TONKO. Well, and thank you. And just to sum it up, does Federal RD&D for wind energy support United States jobs, private investments, particularly in rural communities, and clean-energy deployment?

Mr. KIERNAN. We would not have the 114,000 jobs we have and the investment that we're doing annually of \$1 billion a year in rural America were DOE not a partner with us through their R&D work.

Mr. TONKO. Well, I thank you, and I yield back and hope that we can move a version of this bill this Congress. And with that, I thank you again, Mr. Chairman.

Chairman LAMB. OK. Before we bring the hearing to the close, I want to thank our witnesses again for testifying before us today.

The record will remain open for 2 weeks for additional statements from Members and for any additional questions the Committee may ask of the witnesses.

The witnesses are now excused, and the hearing is adjourned.
[Whereupon, at 11:38 a.m., the Subcommittee was adjourned.]

