Statement of Stephen J. Eglash
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to the
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Subcommittee on Energy
Hearing on Advancing Solar Energy Technology
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Chairman Weber, Ranking Member Veasey, Chairman Smith, Ranking Member Johnson, and members of the Subcommittee, my name is Steve Eglash and I am pleased to share my perspective on advancing solar energy technology. I am a staff member at Stanford University where I am Executive Director of Strategic Research Initiatives in the Computer Science Department. I am testifying in my individual capacity and my views do not necessarily reflect those of Stanford University.

My career spans the fields of energy, materials, data science, and artificial intelligence. I have worked in small and large companies, venture capital, academia, and national labs. During 2007, I was co-leader of a solar energy strategic planning process for the U.S. Department of Energy and the National Renewable Energy Lab. During 2007–08, I was CEO of the solar energy startup company Cyrium Technologies. I have been at Stanford since 2010, where I am responsible for creating and managing research programs, often involving collaboration between industry and academia. I was one of the architects of the Bay Area Photovoltaic Consortium, an innovative collaboration between the U.S. Department of Energy, universities, national labs, and industry. The Bay Area Photovoltaic Consortium is led by Stanford and the University of California at Berkeley. I was founding Executive Director of Stanford's Energy and Environment Affiliates Program. I was Co-Chair of the SLAC National Accelerator Laboratory-Stanford Energy Task Force in 2014.

I was a speaker at the U.S. Senate Committee on Energy & Natural Resources Science and Technology Caucus in 2006. I presented testimony on the challenges and opportunities of the Internet of Things to the California State Assembly Select Committee on Emerging Technologies in 2015. I am a former Board member of the Materials Research Society, former Utilities Commissioner for the City of Palo Alto, and I am currently Chair of the Santa Clara University College of Arts & Sciences Leadership Board. I have a PhD and MS from Stanford and a BS from UC Berkeley, all in electrical engineering. I have four patents and more than 50 publications including a recent paper on the innovation process.

I. The Imperative for Federal Funding of Research

There is tremendous benefit to continued federal investment in research in solar energy and other fields, provided we follow best practices, because this investment improves U.S. industrial competitiveness, strengthens our nation's economy, and creates jobs. The federal government is uniquely well positioned to fund research, the results of which enable industry to develop new and improved products and services, achieve greater efficiency and operational excellence, and invent new business models. Industry often can't afford this research on its own because the technologies are too numerous and broad, each individual project too risky, and in some cases the time to payoff too long.

Federally funded research must be appropriately focused and effectively managed, if it is to lead to good return-on-investment and benefit for U.S. industry. Fortunately, we can turn to exemplary models and identify best practices. The U.S. government, academia, and industry each have unique roles and have to work together across the entire innovation pipeline. Government has the resources to fund research, act as a bridging institution, and convene across academia, national labs, and industry. Universities and national labs are excellent places for innovative research. Industry has insights on real-world opportunities and challenges, as well as the resources for commercialization and large-scale impact.

In fact, this triad of government, universities, and industry is one of our country's great strengths and it can lead to huge competitive advantage for U.S. industry.

II. The Need for Further Research in Photovoltaics

The U.S. Department of Energy's Solar Energy Technologies Office launched the SunShot Initiative in 2011 with the objective of making solar electricity costs competitive with other generation sources by 2020, without subsidies. The SunShot 2020 goal for utility-scale solar generation was achieved three years early in 2017. This is a terrific result because it has accelerated the deployment of residential and utility-scale solar energy.

As impressive as this is, it is only the beginning and there is a need to go further. The cost of photovoltaic-produced energy is now comparable to the cost of electricity from coal- or natural gas-fired power plants on a leveled-cost-of-energy (LCOE) basis, but these fossil-fuel power plants are dispatchable—that is, they provide power at any time whenever it is needed—whereas solar is not. Further reductions in the cost of solar electricity will lead to higher levels of penetration and will lower the average cost of electricity.

The next steps in solar panel research are higher performance through new and improved materials, larger panels leading to reduced cost of manufacturing and installation, reduced capital equipment costs for factories, and improved reliability for longer lifetimes.

Further DOE-funded research in solar energy is important for another reason—it is critical to U.S. competitiveness. If the U.S. develops technology for the next generation of improvements in photovoltaics then we have an opportunity to expand manufacturing and increase jobs. On the other hand, if the U.S. doesn't do this research then other countries will and they will reap the benefits instead of us.

As a utilities commissioner for the city of Palo Alto, California, which runs its own municipally owned utility, I learned firsthand the value of investing in solar and wind generation because the recurring cost of generating electricity using solar or wind is very low. All forms of energy production require an initial investment in plant and equipment. Natural gas, oil, and coal power plants require a continuing source of fuel, which is a major component of the cost of generating electricity from these plants. In contrast, the fuel for solar and wind power plants is free and the only recurring cost is operations and maintenance.

Of course, fossil fuel, nuclear, and hydroelectric power plants are dispatchable, whereas solar and wind plants require sunlight or wind. It turns out this is not a problem, because the ever-decreasing cost of solar and wind power generation coupled with technological advances are providing the means to use solar and wind generation to satisfy an increasing fraction of our energy needs. Batteries and other forms of storage allow us to store wind- and solar-generated electricity for later use. Load shifting enables some energy users to shift to times when demand is low and energy is plentiful. Technologies like concentrating solar power with thermal storage can provide solar power on demand, even when there is no sunlight. Most exciting of all, further advances in solar energy, catalysts, and chemical processes will lead to solar fuels, which are liquid fuels that can replace other chemical fuels in energy storage, energy generation, and transportation.

III. The Unique Roles of Government, Universities, and Industry

Different organizations are best suited for different roles in the innovation ecosystem. Government organizations like the U.S. Department of Energy can translate policy into action, weighing and balancing goals, assuring fairness, and protecting national interests. Government organizations can act as bridging institutions, facilitating knowledge transfer between those who conduct research and those who apply the results of research. Governments are uniquely suited to impose policies, standards, and incentives. They are also a major source of research funding.

Universities excel at education, intellectual scholarship, and workforce development. Many universities also excel at out-of-the-box thinking and developing innovative solutions. Industry can identify real-world opportunities, challenges, and constraints, thereby informing the research agenda. Industry can also enable large-scale impact by commercializing technologies and developing sustainable business models. Many companies also provide valuable financial support to university research programs.

Portions of this section on the roles of government, universities, and industry are from S.J. Eglash and S.M. Rizk, *MRS Bull.* **41**, 479 (2016).

IV. Bay Area Photovoltaic Consortium

The Bay Area Photovoltaic Consortium (BAPVC) is an exemplary model for federally funded research. It was created in 2011 by the U.S. Department of Energy (DOE), Stanford University, and the University of California at Berkeley. The objective of the BAPVC is to perform industry-relevant cutting-edge research on photovoltaic modules enabling high efficiency and low production costs, thereby strengthening the U.S. photovoltaic industry. The BAPVC is a novel and innovative collaboration between the DOE, the U.S. solar industry, universities, and national labs. The BAPVC established a new structure where industry sets the research priorities, professors at universities develop research proposals and conduct the research, and the DOE, academia, and industry work together to manage the program.

U.S. solar companies become members of the BAPVC by paying a membership fee and agreeing to contribute their expertise and perspective. These industry members are a critically important part of the BAPVC. In an advisory role, they identify research priorities, help set the research agenda, review and downselect proposals, review projects, and guide research. University researchers develop proposals, thereby preserving academic freedom. The DOE provides oversight and most of the funding.

The BAPVC developed innovative technologies in a close cooperation with industry that facilitated technology transfer and commercialization. It educated and trained a large number of graduate students and postdocs, providing them with an opportunity to interact and collaborate with solar industry leaders, thereby contributing to workforce development. The BAPVC created an interactive ecosystem comprising leaders from government, universities, national labs, and industry. The resultant interactions and collaborations catalyzed a generation of disruptive ideas. Companies praised the BAPVC for providing access to cutting edge technology and access to a highly trained workforce. Professors appreciated the real-world insights and paths to commercialization.

The BAPVC was remarkably successful. Representative research highlights include CdO transparent oxides, thin-film InP solar cells, ultra-thin silicon devices, perovskite/Si tandem cells, and light-trapping structures for CIGS thin-film devices. The BAPVC also developed technology roadmaps. U.S. solar industry companies were able to access advanced technologies and recruit a highly trained workforce. Those technologies enabled companies to improve device performance and reduce cost.

BAPVC researchers have produced 156 scientific publications, filed 12 patent applications, and received a large number of awards for their research. The BAPVC has trained 57 MS and PhD students and postdoctoral scholars who are now employed in industries such as solar energy, semiconductors, solid state lighting, wireless communications, data science, and the Internet. The BAPVC has resulted in technology transfer to industry in solar cell contact technology, new photovoltaic materials and structures such as perovskite materials and tandem solar cells, and characterization techniques like spectroscopic ellipsometry. The research has led to new research collaborations, new funded research programs, and collaborations between academic researchers and numerous small and large solar energy companies and large technology companies like General Electric and DuPont.

The success of the BAPVC is due in part to a seamless integration of research and application that was responsive to the needs of industry, the ideas of researchers, and the priorities of the DOE. The BAPVC incorporated sophisticated cost modeling to assure that technologies could be deployed cost effectively. As the program continued, in response to requests from the solar industry and the DOE, the BAPVC expanded its research focus to include research leading to reductions in capital equipment costs for PV manufacturing and improvements in solar cell lifetime in the field to 30 years and beyond.

The success of the BAPVC extends far beyond Silicon Valley. The BAPVC funded research at universities nationwide and worked with companies nationwide, leading to a geographically diverse and broad effort that provided benefits across the country. Of course, the BAPVC is just one piece of a larger research infrastructure where support for innovative and impactful research is contributing to our nation's success.

V. Conclusion

Federally funded research on technologies such as solar energy helps U.S. competitiveness and creates jobs. Continued U.S. Department of Energy funding for solar energy research will strengthen and expand the U.S. solar industry, reduce energy costs, and improve our energy independence. Public-private partnerships assure that federally funded research targets the right problems and results in successful technology transfer to U.S. industry.