



ERC for Quantum Energy and Sustainable Solar Technologies (QESST)

Arizona State University (lead institution)

Harnessing sunlight to meet the terawatt challenge

A National Science Foundation Engineering Research Center since 2011 (co-funded with DOE)

Partner Institutions:

- ***California Institute of Technology***
- ***University of Delaware***
- ***Massachusetts Institute of Technology***
- ***University of New Mexico***

Electricity is the lifeblood of modern society—powering everything from cities to pacemakers—and the demand for electricity continues to grow. The ERC for Quantum Energy and Sustainable Solar Technologies is transforming the existing electricity generation system, making it sustainable, ubiquitous, and multifunctional by developing photovoltaic (PV) and quantum energy converters that fundamentally alter how energy is generated. Photovoltaics leverages one of the 20th century’s greatest scientific advances—quantum mechanics—to realize electricity generation that is fundamentally different from other electricity generation. QESST seeks to accelerate implementation of PV technologies through the collaborative development of advances in PV device design that allow rapid implementation and growth. This requires advances in photovoltaic concepts, technology, and education as well as application and integration of sustainability concepts and active engagement from industrial collaborators.

Achieving a sustainable energy system is one of the defining challenges of the coming decades. To tackle this challenge, QESST is investing in a research portfolio that spans the fundamental knowledge base, enabling device technology, and engineered systems. This research also spans the three commercial PV technologies—silicon, thin films, and tandem devices—with the ultimate goal of exploiting insights and experience from one technology platform to another to ensure that lessons learned from more mature PV device engineering are transferred to novel approaches. While transforming the installed energy infrastructure that has been built over the last 100 years is a massive undertaking, solar energy has the unique capacity to meet the entire world energy demand; and by overcoming technological challenges that threaten continued growth, PV will have sufficient capacity to meet the entire new U.S. electricity demand within 5 to 10 years. QESST is addressing the Terawatt Challenge—the need to produce massive amounts of electricity cleanly, cheaply and sustainably—to supply the increasing global demand for energy.



A photovoltaic solar cell produced by QESST

Research

Through photovoltaic research, QESST seeks to continually improve the efficiency, economic viability, and sustainability of PV systems.

There is no one “silver bullet” material or revolutionary device that will transform the existing electricity generation system, making it sustainable and cost-effective. The QESST approach integrates technology and participants and creates a bridge between disconnected PV technologies and research and development efforts. Key to the success of QESST will be a mapping of the interwoven technology and process advancements that will result in a continuously expanding implementation of revolutionary new approaches to enhance PV performance, reduce cost, and enable new functionality that will:

- lead to transformative breakthroughs in the performance and cost of sustainable energy through advances in material sciences, particularly relating to surfaces, interfaces and

defects, photonics, energy conversion processes, advanced nanofabrication and characterization technologies, and new multifunctional energy conversion devices;

- enable the PV industry to continue to expand production by developing technologies that support the scale-up of new devices into large-scale manufacturing; and
- introduce readily scalable, highly efficient, transformative PV technologies that circumvent cost/performance trade-offs and maintain compatibility with PV manufacturing techniques.

The QESST research plan is divided into three planes: fundamental knowledge is generated in Advanced Enablers (Thrust 1) which lead to device development in Moore’s Law (Thrust 2). The devices built in Thrust 2 are integrated into manufacturing systems with Terawatt Manufacturing (Thrust 3). Each thrust spans the three commercial PV technologies—silicon, thin film, and tandem—seeking common technical barriers and solutions to enable hybrid approaches to PV. In parallel, research testbeds demonstrate QESST technology in a Student-Led Pilot Line (Testbed 1), Module Integration and Communication (Testbed 2), and Advanced Technology Modules (Testbed 3).

Education

Focused around the challenge of meeting the future demand for energy in a clean and sustainable way, the QESST ERC Education Program aims to build a diverse pipeline of creative, motivated, knowledgeable students who will drive the future PV industry. To support this mission, QESST seeks to engage students in learning foundational content and to provide exposure to engineering design from early scholars to post-graduate leaders.

University Education: Through participation in QESST-sponsored workshops, professional development activities, and research experiences, both graduate and undergraduate students will develop deep content knowledge in Photovoltaics and an identity as PV engineers and QESST scholars.

K-12 Education: Through the development of educational units, QESST plans to use solar energy and photovoltaics as an avenue for teaching the current standards-



Dr. Christiana Honsberg (center left) with QESST faculty and staff at ASU Day at the Arizona State Capital

based curriculum while promoting an interest in science, technology, engineering, and mathematics. Through these units elementary students will engage in hands-on, inquiry-based learning experiences. In order to provide these learning experiences, teachers in partnering districts will be involved in professional development focused on increasing their content knowledge and developing strategies for implementing inquiry-based STEM lessons in the classroom.

Young Scholars: As part of the young scholars program, high school students will interact with QESST scientists, engineers, and industry partners as they explore the variety of possible career pathways within the field of photovoltaics.

Outreach: Through university-sponsored events offered throughout our partner institutions, QESST aims to educate the broader community about the ongoing research of the Center as well as the benefits and potential of photovoltaics in general. Our goal is to engage stakeholders (e.g., community members, future engineers, and policy makers) in discussions about photovoltaics, provide demonstrations of the possibilities of photovoltaic energy, and pique the interest of young children and adolescents in exploring engineering and solar energy as possible career paths.

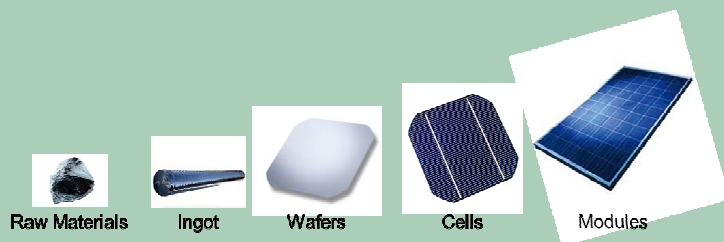
Industry Education: Each partner institution has long-established ties with industry as well as a history of entrepreneurship. We leverage these relationships to provide students with internship opportunities, fireside chats with leaders of the PV industry, direct instruction and instructional innovations originating from our industrial partners, and small workshops led by industrial leaders.

Innovation Ecosystem

The photovoltaics industry is a highly fragmented industry with over 700 companies participating along the PV value chain, as depicted below. QESST, through its Industrial Membership Program, reaches out to large and small key participants along the PV value chain. In doing so, QESST identifies research topics that benefit industry, align



QESST students developing solar cells on the Testbed 1 Pilot Line



Elements of the photovoltaic value chain

with QESST's vision, and help students advance their career potential. The knowledge created is transferred to industry through papers, presentations, workshops, IAB meetings, retreats, and other forms of knowledge exchange. When intellectual property is created, companies have a means to obtain non-exclusive, royalty free, commercial license rights to such IP. If the know-how or IP is best suited for a spin-out environment, QESST will leverage its university innovation systems to help insure that the spin-out is nurtured, mentored, and supported to increase the probability of commercial success.

Facilities

QESST's Solar Power Lab (SPL) is situated in the Arizona State University Research Park. The SPL is a 4000 square foot state-of-the-art clean room with extensive handling for high purity gases and sophisticated semiconductor process equipment. Additional ASU-based facilities for characterization

include the NanoFab and the LeRoy Eyring Center for Solid State Science. QESST partners have specialized facilities for a variety of semiconductors including III-V processing, thin films, and nano-structured solar cells.

The Center will occupy newly renovated headquarters in the Arizona State University Engineering Research Center building. The headquarters, located in the heart of the Fulton Schools of Engineering, will include QESST administrative offices, dedicated outreach and gallery space, and a student synthesis workshop.

Center Configuration, Leadership, Team Structure

Tackling the Terawatt Challenge requires both technical depth and breadth of comprehension. QESST pulls strength from the broad diversity of disciplines and backgrounds of its individual participants. Specifically, QESST faculty includes individuals with disciplinary background

from 14 distinct fields. While a significant fraction are from electrical engineering (~40%), no single discipline represents a majority of the faculty and thus sets the research direction of QESST.

The overall direction and management of the Center is the responsibility of the QESST executive leadership group, which receives input from the National Science Foundation and the Department of Energy; our Industrial, Innovation and Scientific Advisory Boards; the Council of Deans, and the QESST Student Leadership Council. Integration of the research among the partner universities is conducted by the executive leadership group in concert with the QESST Co-Directors at each of the Academic Partner universities and the leaders of the Center's research thrusts and testbeds.

Center Headquarters

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Rendering of QESST lobby/gallery space

