QESST

newsletter ▪ winter 2016, volume 6

Quantum Energy and Sustainable Solar Technologies

AN NSF-DOE ENGINEERING RESEARCH CENTER

research highlights

Improving recycling of PV systems at a terawatt scale

Photovoltaic deployments are accelerating worldwide to meet climate goals and reduce the reliance on carbon intensive fossil fuel sources of electricity. With a typical 25 year lifetime, current installations will necessitate environmentally responsible recycling methods to meet regulatory requirements and manage the significant increase in the volume of end of life PV systems. Research by Dwarak Ravikumar, a QESST Scholar and PhD candidate in Civil, Environmental and Sustainable engineering at ASU, focusses on quantifying the environmental impacts of PV recycling operations. Dwarak has modelled the material and energy flows for the current recycling operations at First Solar, the world's largest PV recycler, to show that the recycling bulk materials like steel, aluminum and copper from the balance of systems recover around 24% of the initial energy invested in manufacturing the CdTe PV system.

Current physical delamination processes that eliminate the ethylene vinyl acetate (EVA) polymer, which binds glass and CdTe semiconductor in the module, is an environmental hotspot. This research is now investigating, at a pilot scale, emerging alternate chemical and heat based processes that can potentially address this hotspot. Based on this experimental data at a pilot scale, this project will advance environmental impact assessment methods, to prospectively identify environmentally favorable pathways for the emerging recycling processes at an industrial scale.

This work has been accepted for publication in Progress in Photovoltaics and can be accessed at http://onlinelibrary.wiley.com/doi/10.1002/pip.2711/abstract

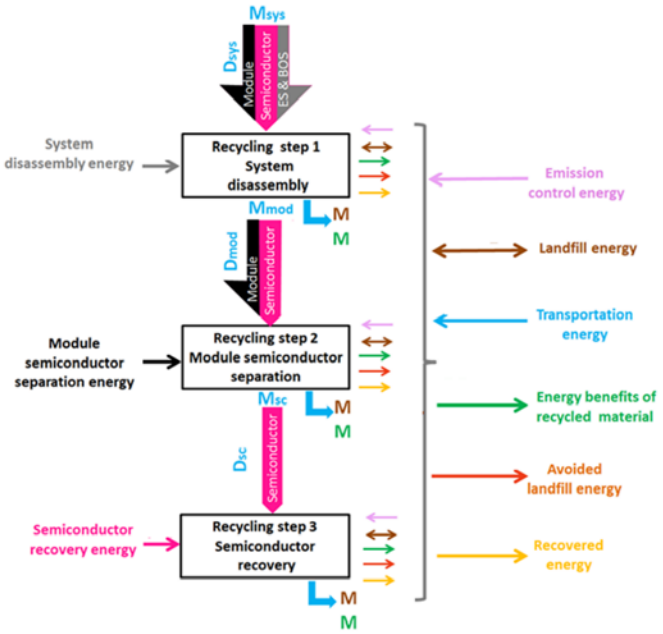


Figure: Energy and material flows for the three step recycling process for end of life CdTe PV system

important dates

All QESST Vidyo Conferences
March 21st
April 4th
April 18th

Night of the Open Door
February 27th, ASU campus in Tempe

QESST Solar Energy Research Experience for Undergraduates Application Deadline
March 15th

MRS Spring Meeting
March 28th-April 1st, Phoenix AZ

Annual Report due to NSF and DOE
March 28th

QESST Site Visit
May 2nd-4th, Tempe, AZ

QESST Solar Energy Research Experience for Undergraduates
May 31st - July 29th, Tempe, AZ

IEEE Photovoltaic Specialist Conference
June 5th-10th, Portland, OR

NREL Hands-On PV Experience Workshop
July 24th-30th, Golden, CO

Impact of Solar on Residential Resale

Jason O'Leary, a QESST Scholar at ASU, has conducted a survey of solar homeowners in Maricopa county, Arizona to examine the marketplace for leased vs owned systems. Recent media stories and studies have portrayed solar leases as dragging down resale prices of existing solar homes. However, these analyses have generally treated all leased systems the same when compared to owned systems. O'Leary's hypothesis is that prepaid lease arrangements are treated differently and more positively in the marketplace than leases with payments remaining at the time of the home's sale.

To test this hypothesis, a survey was designed to rigorously capture empirical data on both prepaid leases and those with remaining lease payments at the time of sale, as well as owned systems for comparison. It also measured behavior, attitudes & beliefs toward solar, the environment, and various economic factors through qualitative questions. Finally, it included a standard demographics panel as well as several questions on residential solar battery storage.

The survey was mailed to people who recently purchased previously owned homes with solar PV systems that were already installed by the previous homeowners to measure how solar PV acts as a feature in the real estate marketplace, particularly when leases are involved. The two major factors used for quantitative measurement were price per square foot ($/sq ft) and days on market (DOM), both common indicators in the real estate market. The generally accepted theory had been that the homebuyer's preference for owned systems would yield a premium price and that leased systems would not only sell for less but would also take longer to sell due to complications in transferring the lease to a new owner.

Based on initial results from 264 respondents, this survey indicates that prepaid leased systems, in aggregate, have been treated virtually the same as owned systems when measured by both major indicators. Both prepaid and owned systems also yield a slight premium compared to non-solar homes. As predicted, systems with payments sold for less than both solar and non-solar homes. However, while selling for a lower $/sq ft, they also sold faster than either leased or owned systems as well as non-solar homes, based on the DOM. This surprising result could be due to several exogenous or qualitative factors, including demographics and sub-market preferences not immediately apparent through high level, quantitative data analysis.

This work was presented at the 2015 Behavior, Energy and Climate Change conference.

	Owned Solar System	Pre-Paid Solar Lease	Solar Lease with Outstanding Payments
Price ($/sq ft)	$147	$145	$121
Days on Market	106	104	68

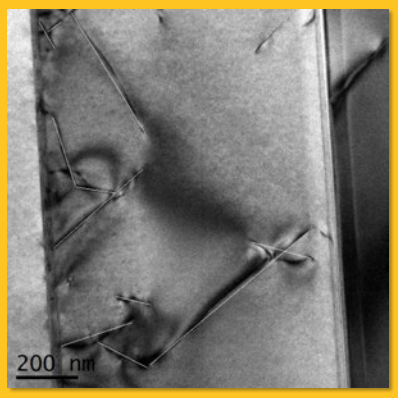
AlGaSb Based Solar Cells

In collaborative work between ASU and UNM, a new AlGaSb 4-junction bonded solar cell demonstrates the path for concentrating solar cells to reach efficiencies in excess of 50%.

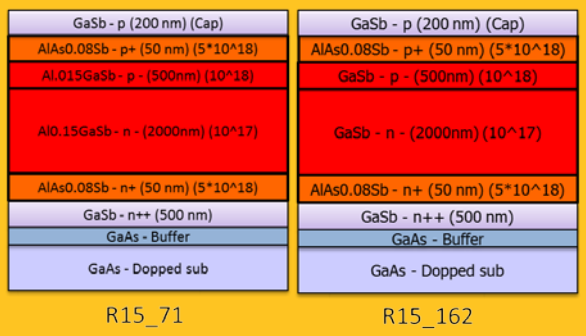
For 4-junction and 5-junction solar cells, detailed balance calculations show that under high concentration, the optimum lowest band gap reduces from ~0.7 eV to less than 0.5 eV. This lower band gap is out of range for the current generation of III-V materials for multijunction solar cells. In order to realize the high efficiencies that are enabled by the reduced band gap, the new cells must match the performance of current III-V or Si solar cells for Woc ($Woc = qEG - Voc$). QESST research at ASU and UNM is investigating Sb-based compound semiconductors as a promising candidate for low band gap multijunction solar cells as Sb-containing alloys, with device results for a GaSb solar cell grown on both GaSb show the potential for a GaSb solar cell with a Woc ~ 0.4 eV.

In order to translate these results to a commercially relevant structure, it is desirable to grow Sb-containing alloys on non-native lower cost substrates, such as GaAs. For this work, AlGaSb was grown directly on GaAs substrates using molecular beam epitaxy and were compared to control structures of GaSb solar cells grown on GaAs. Using XRD, TEM and AFM, the structural properties and material quality were characterized to specify the extent of relaxation of elastic strain and the spatial distribution of preferable crystalline defects in the epitaxial layers

These results will be presented at the upcoming 2016 IEEE Photovoltaic Specialists Conference in Portland with QESST Scholar Ehsan Vadiee as lead author.



Cross-section TEM image of AlGaSb/GaSb/GaAs sample with specificed projected dislocatoin lines.



Schematics of Sb-based solar cells grown on GaAs substrates.

education & outreach

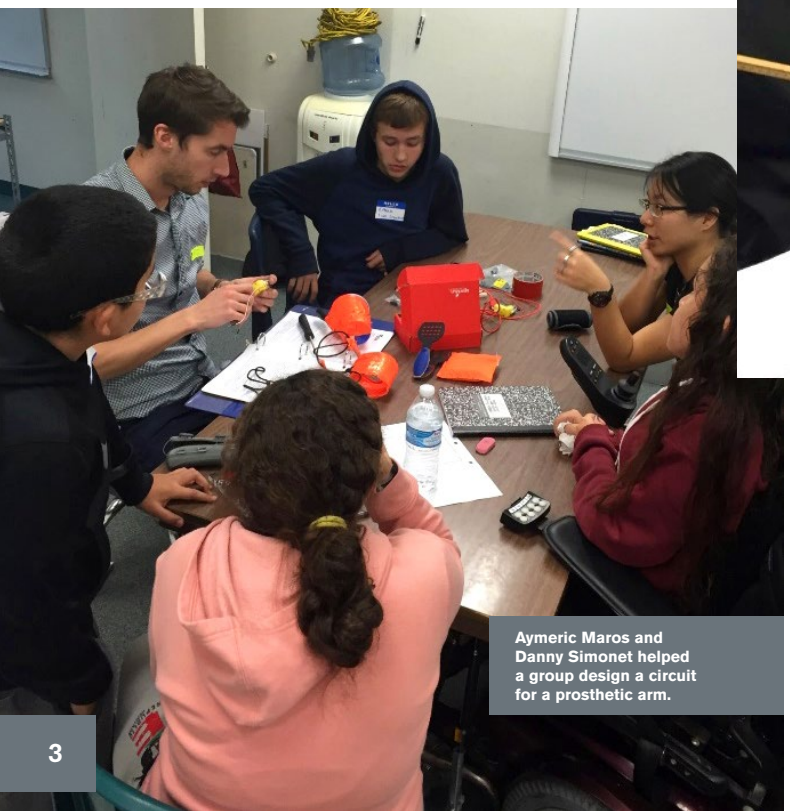
Night of Open Door

On February 27, 2016, QESST will host Arizona State University's annual Night of the Open Door inside the Engineering Research Center from 4pm until 9pm. QESST designs activities to engage students of all levels in learning about solar energy and to excite the next generation of PV engineers. Community members are encouraged to stop by to learn about QESST and the Terawatt Challenge. This is a rare opportunity for the public to get a behind the scenes look at the lab space that house some of our most innovated solar projects and to interact with students, faculty and staff.

Math, Engineering and Science Achievement (MESA)

In an on-going effort to support our partnerships with MESA and the Alhambra Elementary School District, QESST Scholars volunteered their time and participated in 3 different after school programs during the 1st week of January. The scholars assisted with many engineering design challenges such as hydropower, egg delivery, prosthetic arm, duct tape, and the solar car challenge. They also emphasized the importance of an engineering design notebook.

QESST Scholar Abhinav Chikhalkar works with a middle school student as they design a trebuchet

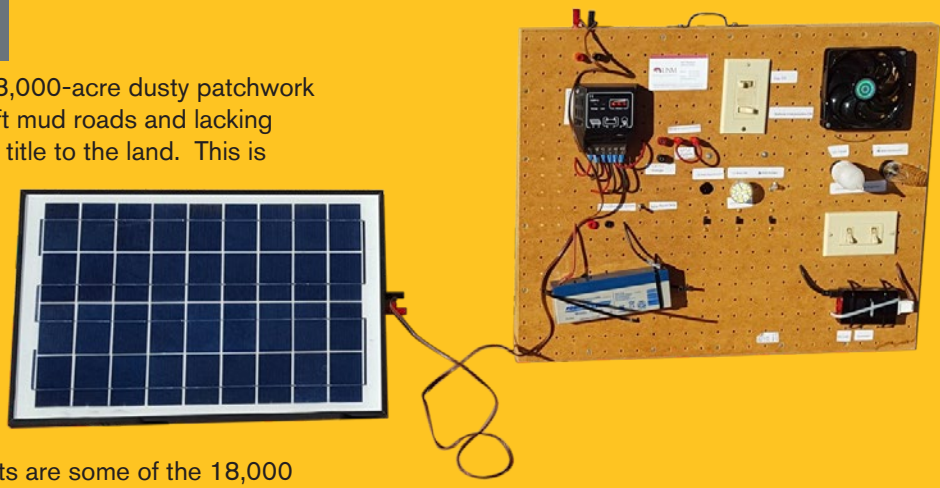


Aymeric Maros and Danny Simonet helped a group design a circuit for a prosthetic arm.

These challenges provide students the opportunities to use creativity and innovation as well as engineering practices as they work together to design and build their projects. For the past 3 years, QESST has worked alongside MESA and sponsors the solar car challenge. The state competition will take place at Arizona State University on April 23, 2016.

QESST Outreach in New Mexico

Just 10 miles from downtown Albuquerque lays an 18,000-acre dusty patchwork of homesteads and trailers, crisscrossed by makeshift mud roads and lacking in utilities, official addresses and in many cases clear title to the land. This is Pajarito, and in October, QESST graduate students Emma Renteria and Sadhvikas Addamane and Outreach Coordinator Stefi Weisburd visited the community center at the mesa's edge to make solar cars with students in the afterschool program run by Albuquerque Public Schools (APS) Title 1 Homeless Project. With the help of a residential solar system demo board that UNM brought, two middle school students described their home solar systems, which use golf-cart batteries. These students are some of the 18,000 people in New Mexico who live off-the-grid. QESST collaborators from UNM will bring solar cars to all 6 of the APS Homeless project afterschool sites, which serve 115 elementary and middle school students.



The residential solar system demo developed by UNM which runs 3 types of light bulbs and a fan.

Building an inclusive environment

The winter saw two events by QESST Diversity Director Prof. Delia Saenz as part of efforts to build an inclusive environment.

First, Dr. Saenz visited the College of Engineering at Iowa State University and the Engineering Research Center for Biorenewable Chemicals (CBiRC) in November. While at Iowa State, Dr. Saenz discussed how the participation of women and people of color in STEM disciplines has remained relatively minimal despite concerted efforts to promote diversity. To address this, Dr. Saenz gave an overview of the factors that have been identified through social science research as potential contributors to this situation. Specifically, she discussed how social psychological elements related to structure, content, and process play an important role in inhibiting or facilitating inclusion within educational settings. The work suggests that interventions must be broad-based and include cultural institutional changes within the academy.

A second inclusion activity took place in January involving QESST Scholars from ASU and UA (by video). Using a focus group modality, male and female graduate students discussed challenges faced by women in STEM graduate programs. The discussion included both the perspective of women as targets of microaggressions and that of men, as witnesses to such events and in their potential role as allies. Different scenarios were considered and discussed, as was the need to create shared strategies for eliminating gender bias in the classroom and the lab. A follow-up session, open to all QESST Scholars, will be scheduled for later this spring, and will focus on evidence-based practices for building a learning environment conducive to success. Take-away tools (responses, strategies) for elimination of bias and for career success (negotiating jobs) will be reviewed and practiced. Stay tuned for information on scheduling.

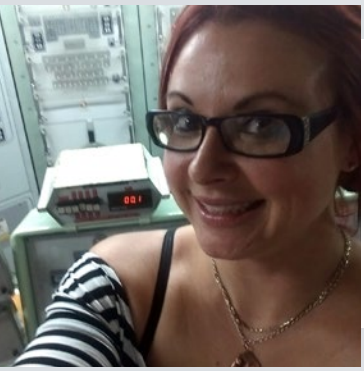
Where are they now?

Every summer, QESST hosts Research Experiences for Undergraduates (REU), Veterans (REV) and Young Scholars (YS). Under the guidance of student mentors and QESST faculty, participants are provided a hands-on experience making solar cells and working on a research problem.

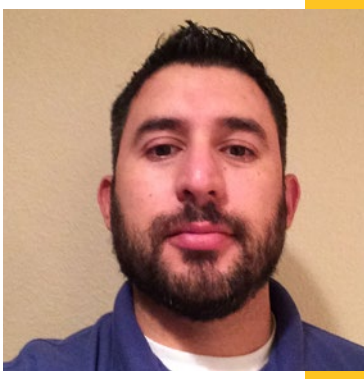
The largest summer program is hosted at Arizona State University and takes advantage of ASU's Solar Power Lab and the QESST Student Led Pilot Line. The Student Led Pilot Line hosts approximately 10 to 15 students each summer. Participants come from across the U.S. with a wide variety of backgrounds and educational levels. Many of the student participants get their first authentic research experience through the QESST summer education program.

QESST evaluators have maintained contact with over 80% of the students who have participated. Of these students, 100% have either graduated in engineering or have continued in their engineering majors. Many of these young men and women have pursued majors or careers in the energy field. This month we feature five of our summer program participants including Cedricka Dalton and Candice Wuertz, REU participants in the first QESST summer cohort in 2012 at ASU; Saul Tiscareno and Michael Minjares who have participated in the QESST REV program at ASU; and Adrian Armendariz, a young scholar who participated in the QESST summer program at the University of New Mexico.

Cedricka Dalton (QESST 2012 REU at ASU) is an Electronics Engineer at the Mid-Atlantic Regional Maintenance Center on Norfolk's Naval Station Base. Cedricka graduated in the spring of 2014 from Norfolk State University with a cum laude Bachelor's degree in Electronics Engineering and Mathematics. She is now in her second semester of pursing a Master's degree in Engineering Management at Old Dominion University in Norfolk, Virginia. In her spare time, she volunteers by mentoring and tutoring students at the local high schools in her area. She also contributes to the organizations she joined in her undergraduate career Institute of Electrical and Electronics Engineers (IEEE) and the National Society of Black Engineers (NSBE).



Candice Wuertz (QESST 2012 REU at ASU) has been heavily involved in residential PV installation. She has experience working in multiple environments of PV installation. These include small startup and large residential and commercial PV installation companies in Phoenix, Arizona. She currently works at APS – a major electricity utility in Arizona.



Saul Tiscareno (QESST 2013 REV at ASU) is employed as a Presales Engineer with Gehrlicher Solar America – a company of M+W Group. Saul graduated from Arizona State University in May 2014 with a Bachelor's degree in Electronics Engineering with a focus in alternative energy. While at ASU, Saul helped launch undergraduate student clubs such as Green Devils, International Service Devils and the Global Resolve Club. These clubs help to support sustainability and focus on community service projects in underdeveloped communities. Saul is a former Sergeant in the United States Marine Corp.

Michael Minjares (QESST 2014 REV at ASU) was accepted into ASU's electrical engineering program in the spring of 2014. Michael began his college career after two tours of duty in Iraq. During his first semester as an undergraduate, he served as a leader on a service project in Monument Valley, Arizona. The purpose of this student driven project was to design and build a photovoltaic system for a family living in the Navajo Nation. Michael was able to share what he has learned in the lab, while learning about the history and lives of the Navajo people.

Adrian Armendariz (QESST 2015 YS at UNM) was recently accepted to attend the University of Pennsylvania on full scholarship. Adrian plans on pursuing a major in mechanical engineering. His favorite high school course is AP calculus. Adrian hopes to someday return to Albuquerque and "give back everything that his city and community has given to him."

industry and innovation program

QESST Scholar honored by the National Science Foundation

During the last QESST Industry Advisory Board meeting, the QESST Industrial Advisory Board voted Pablo Guimerá Coll as the best "Perfect Pitch" competitor amongst all QESST Perfect Pitch competitors. Pablo then followed up by winning the national level competition the following week in Washington D.C.

The Perfect Pitch competition is held across all 19 active NSF Engineering Research Centers consisting of 90 universities such as Berkeley, Harvard, Stanford, Georgia Tech, MIT, Purdue, UCLA, and Caltech. In the 90 second Perfect Pitch, Pablo was able to explain how his research will help reduce the cost of solar energy by using low temperature environments and sound to create silicon wafers from an ingot.

"After winning the internal competition a QESST, I kept practicing the pitch with my research group. This was when I started feeling we could have a real shot of finishing the competition in the top three. During the national competition in Washington, I got to compete against colleagues from other top universities so I knew it would be really hard.

I could not believe it when I was standing in the Caucus Room at the House of Representatives Building and heard my name as the final winner. It was an incredible experience. Besides the competition itself during those few days in Washington, I had the chance to speak to very important people - industry leaders, scientists, congressmen, ambassadors, and the NSF Director," Pablo explained.

QESST Industrial Advisory Board voted Pablo Guimerá Coll as the best "Perfect Pitch" competitor

(Credit: NSF/Sandy Schaeffer)

Pablo Guimera Coll was born in the Canary Islands, Spain. He received his B.Sc. in Materials Physics from Complutense University in Madrid before getting his B.Sc. and M.Sc. in Physics at Kansas State University. During his Masters, his research was focused on the synthesis and reshaping of metal nanoparticles. This work resulted in the proposal, as a coauthor, of the patent "Direct Dissolution of Bulk Materials to Nanoparticles". In fall 2015, Pablo enrolled in the Materials Science and Engineering PhD program at Arizona State University and joined the Defect Engineering for Energy Conversion Technologies Lab, led by Dr. Bertoni. His current research is focused on producing silicon wafers from an ingot using low temperatures and sound in the process. After his PhD, Pablo is determined to make an impact in society by improving and expanding solar energy around the globe.

partner universities

Arizona State University

Caltech

University of Delaware

Georgia Institute of Technology

University of Houston

The University of Arizona

Massachusetts Institute of Technology

The University of New Mexico

UNSW The University of New South Wales

Imperial College London

東京大学 The University of Tokyo

accepting the challenge

Electricity is the lifeblood of modern society, powering everything from cities to pacemakers. With demand increasing, the electricity generating system faces challenges. These include harmful environmental impacts, threats to national security, resource supply problems, difficulties in powering autonomous applications, and over a quarter of the world's population without access to electricity. These all indicate the need for a new electricity generation system. QEEST addresses these challenges by supporting a system of photovoltaic science and innovation—a system that breaks away from the waste and inefficiencies of unsustainable fossil fuels and generates power using our favorite sustainable and unlimited resource: the Sun.

QESST is an NSF/DOE Engineering Research Center funded in 2011 under cooperative agreement EEC-1041895 and headquarted at Arizona State University

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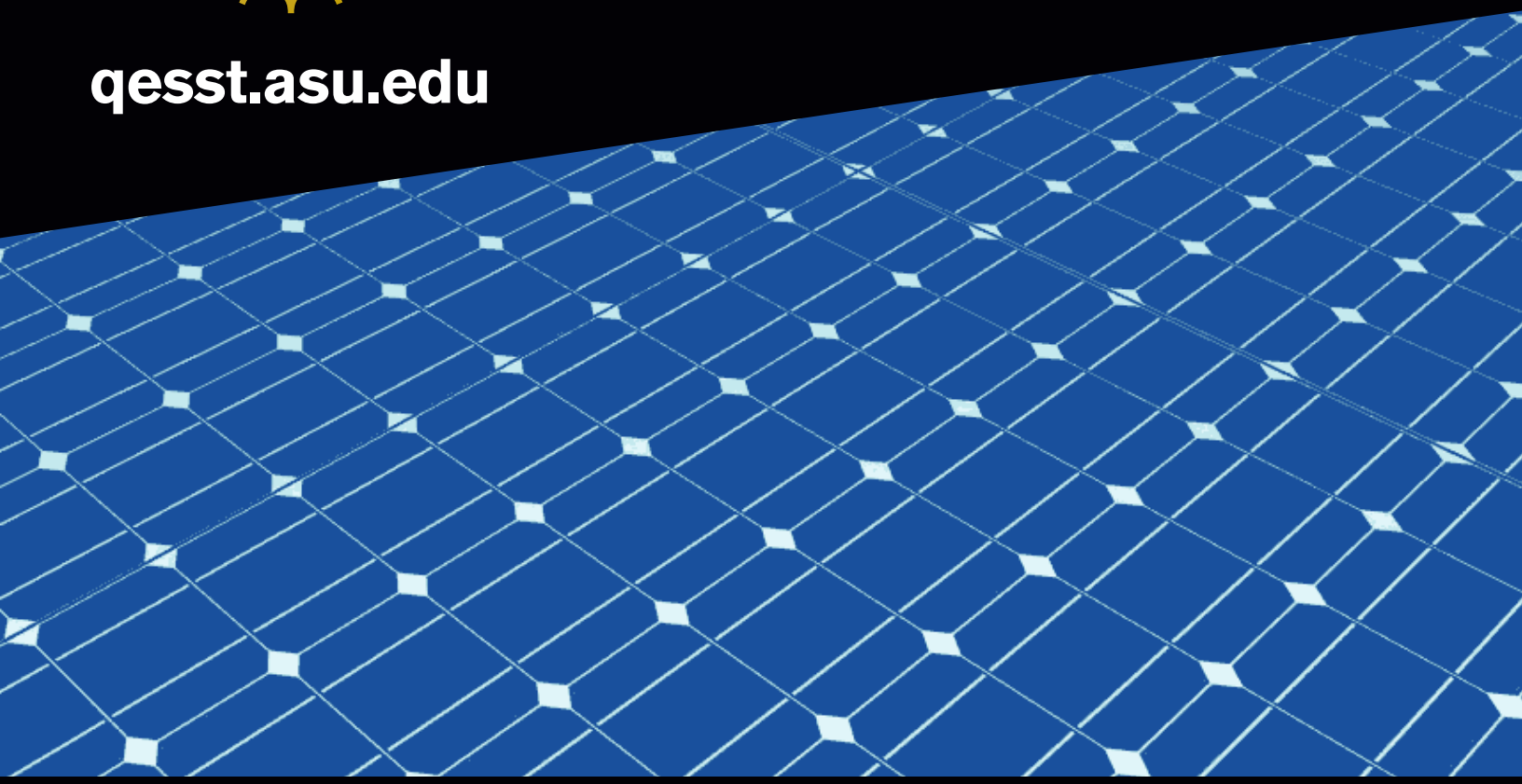

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