



**CLEAN ENERGY
INSTITUTE**

UNIVERSITY *of* WASHINGTON



Annual Report

**July 1, 2021 -
June 30, 2022**

Letter from CEI's Director

Dear friends of CEI,

The 2021-2022 academic year proved pivotal for clean energy and climate action at the University of Washington, and indeed for our state, nation, and planet.

In that time, the UW Clean Energy Institute (CEI) resumed in-person instruction, research activities, and K-12 outreach visits, though the impacts of COVID-19 will be felt for years to come. And the Washington Clean Energy Testbeds returned to full operations in July 2021.

Despite the challenges faced during the pandemic, I'm proud that so many UW students are even more driven to study clean energy and develop solutions for climate change. The passion and intellectual curiosity of CEI Graduate Fellows, Torrance Tech Due Diligence and Science Policy Analysts, and Clean Energy Bridge to Research undergraduates and community college teachers have pushed CEI leadership to think more broadly about the role CEI can play to catalyze a clean energy future.

Indeed, our mission of "accelerating a scalable **and equitable** clean energy future" requires new partnerships on campus and throughout Washington state.

This past summer, CEI partnered with UW's EarthLab and Seattle-based company LevelTen Energy to launch the Clean Energy Scholars Mentorship Program, providing ten undergraduates from diverse backgrounds with the opportunity to work in climate tech and to connect with the Pacific Northwest clean energy community. CEI has also helped recruit new faculty members that study energy and development in underserved communities, explore planning processes that align with Indigenous community values and goals, and that use art to build a "science identity" in kids. As campus climate and energy coalitions continue to build momentum, I'm thrilled by how CEI faculty and students are coming up with new ways to collaborate across disciplines to affect change on the ground in Washington state and beyond.



CEI research and educational programs have elevated the university's role in the region's and nation's energy transition. This past year, CEI faculty led center-scale grant proposals that received over \$100M in new support alongside world-leading partners at other universities, national labs, and industry. And in line with several pieces of state and federal policy, CEI this year received funding to expand the Testbeds' capabilities in battery science and engineering, and to establish a Community Engagement Testbed to support Washington in an equitable clean energy transition.

While Washington state is already a national role model in clean energy, I'm encouraged to see climate change prioritized by federal leadership, with legislation such as the Bipartisan Infrastructure Law, the CHIPS & Science Act, and the Inflation Reduction Act investing hundreds of billions of dollars to stimulate American innovation, build new clean energy resources to reduce our dependence on fossil fuels and imports, and make U.S. electricity grids more resilient. These federal policies aim to stimulate innovation and manufacturing across industry, utilities, national labs, and universities, and to build the workforce needed to make it happen. CEI is well-positioned to create new partnerships with its strong networks of K-14 educators, Testbeds users, and climate tech industry partners.

And finally, in March 2022, the UW Board of Regents approved plans for a new 340,000-square-foot building which will be focused on developing solutions for a healthy planet. The new building, which includes more than 30,000 square feet for the Testbeds, will be located at site W27 in the (newly named) Portage Bay Crossing district west of UW's main campus and is anticipated to be completed in 2025.

We have much to celebrate and act on together.

Thank you for your continued support,

Daniel T. Schwartz



Dan Schwartz

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ABOUT CEI

MISSION

The University of Washington (UW) [Clean Energy Institute's](#) (CEI) mission is to accelerate the adoption of a scalable and equitable clean energy future that will improve the health and economy of our state, nation, and world. To accomplish this, CEI supports the advancement of next-generation solar energy and battery materials and devices, as well as their integration with systems and the grid. CEI creates the ideas and educates the people needed to generate these innovations, while facilitating the pathways to bring them to market.

CEI supports students, faculty, and partners through [education and workforce engagement programs, basic and translational research support](#), and access to [world-class facilities](#).

LEADERSHIP & MANAGEMENT

Established in 2013 with support from the state of Washington, CEI is led by director [Daniel T. Schwartz](#), Boeing-Sutter Professor of Chemical Engineering, chief scientist [David Ginger](#), B. Seymour Rabinovitch Endowed Chair in Chemistry, and administrator Amanda McCracken-Roberts.

In 2017, CEI launched the [Washington Clean Energy Testbeds](#), an open-access facility for prototyping, testing, and scaling climate technologies. Testbeds operations are overseen by Testbeds technical director [J. Devin MacKenzie](#), Washington Research Foundation Associate Professor of Clean Energy, Mechanical Engineering and Materials Science & Engineering, and Testbeds managing director Michael B. Pomfret, Ph.D.

CEI is advised by a UW Trainee and Faculty Advisory Board (TFAB), including two Trainee Advisory Representatives and nine faculty; and an external Technical Advisory Council (TAC) of prominent members of the Pacific Northwest clean energy community.

CEI staff, facilities, and finances are managed by the Collaboration Core, a shared services unit in the College of Engineering.

FACULTY & STUDENTS

CEI's 34 Member Faculty are the core scholars who help define and implement the Institute's energy science and engineering research and educational programs. CEI Member Faculty status is conferred by vote of the TFAB. CEI also has 31 Affiliate Member Faculty who broaden and enrich the institute's research and educational programs. UW faculty interested in joining CEI as an Affiliate Member are invited to apply through the CEI website, with applications reviewed on an as-received basis.

CEI programs support approximately 100 UW graduate students each year: including funding doctoral research, training students in the interdisciplinary Energy Materials, Devices, and Systems lab course, and supporting opportunities to work alongside K-12 schools, investors, and public policy stakeholders. CEI programs are open to all UW students that meet requirements specified in each program, not just those whose advisors are CEI Member Faculty or Affiliate Member Faculty.

CEI-affiliated academic personnel and students are formally managed through their appointing department.

FACULTY RECOGNITION



Corie L. Cobb, professor of mechanical engineering, awarded DARPA Director's Fellowship



Brandi Cossairt professor of chemistry, elected to WA State Academy of Sciences



Jim DeYoreo, affiliate professor of chemistry and materials science & engineering, and Samson A. Jenekhe, professor of chemical engineering, elected to National Academy of Engineering



Daniel T. Schwartz, professor of chemical engineering, receives CleanTech Alliance Board Chair Award



Dianne Xiao, assistant professor of chemistry, receives NSF CAREER, Beckman Young Investigator awards



Matthew Yankowitz, assistant professor of physics, receives NSF CAREER award

CEI STUDENT AWARDS

SCIENTIFIC ACHIEVEMENT AWARD



Dr. Shua Sanchez, (Physics PhD '22) won CEI's 2021-22 Scientific Achievement Award for independently developing a new X-ray diffraction technique to analyze the crystal structures of advanced materials.

“Not only did the CEI Graduate Fellowship provide me with a platform to build my research, but it bolstered my CV and my confidence in applying for other funding opportunities, eventually leading to my postdoctoral position at MIT. ”

-- *Shua Sanchez, CEI Graduate Fellow '16-17*

EDUCATION & OUTREACH AWARD



Miguel González-Montijo (Civil & Environmental Engineering doctoral student) and **Ricardo Rivera-Maldonado** (Chemistry doctoral student) jointly received the 2021-22 Outreach & Service Award for outstanding contributions to CEI K-12 educational programs. They co-developed CEI's first Spanish-language learning resource: **a bilingual climate science fact sheet** which aims to empower K-12 students to discuss climate change and clean energy with their families and communities.

“With the tools and platforms we have received as CEI Graduate Fellows, it's our job to become leaders, to have the difficult conversations with people in our lives about climate change and clean energy. ”

-- *Miguel González-Montijo, CEI Graduate Fellow '21-22*



EDUCATION & WORKFORCE ENGAGEMENT

OVERVIEW

Education is at the core of CEI's mission. CEI helps inspire, recruit, train, and support the next generation of clean energy leaders and innovators through unique education, outreach, and research training programs. These programs serve graduate, undergraduate and K-12 students, K-12 and community college teachers, and the general public. CEI's programs seek to expand participation in STEM by making STEM study and STEM careers more attractive and more attainable for a broader cross-section of the US population.

CEI's signature program for UW graduate students, the CEI Graduate Fellowship, directly funds UW Ph.D. students to explore new directions in clean energy research, while providing opportunities for career development and community engagement. Additional programs for UW graduate and undergraduate students provide interdisciplinary clean energy training as well as specialized opportunities in K-12 STEM education, public policy, and climate tech innovation.

CEI also provides undergraduate students from other universities as well as local community, tribal, and technical college instructors with opportunities to perform clean energy research in a UW lab over the summer. Several of these summer undergraduate researchers have later transferred to UW to complete their bachelor's degree or have been accepted to UW graduate programs.

To support K-12 outreach, CEI staff, students, and faculty have collaborated to develop a comprehensive library of K-12 clean energy lesson plans and hands-on activities in alignment with Next Generation Science Standards. CEI Education & Training Fellows lead their peers — student Clean Energy Ambassadors — on classroom, museum, and public-facing visits across Washington state, wielding science communication skills and UW's excellence in scholarship to bridge the critical knowledge gap between the STEM concepts covered in a conventional K-12 curriculum and the cutting-edge research that is carving the path towards a clean energy future.

CEI GRADUATE FELLOWSHIP

The [CEI Graduate Fellowship](#) funds up to two quarters of clean energy research for 20-30 UW doctoral students each academic year, while providing interdisciplinary training via research seminars, science communication projects, K-12 outreach activities, climate tech networking events, industry field trips, and lab tours. CEI has awarded over 200 Fellowships since 2013. After earning PhDs at UW, these CEI Graduate Fellows have pursued careers in the climate tech industry, U.S. universities, think tanks and other nonprofits, and federally-funded research labs. Here are some examples of where our alumni are now:



Katie Corp
PhD chemistry '19
'15-16 Graduate Fellow

Twelve
(climate tech startup)



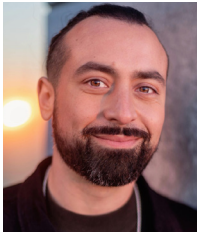
Sarthak Jariwala
PhD MSE '21
'16-17 Graduate Fellow

Palo Alto Research
Center (Xerox)



Nick Montoni
PhD chemistry '18
'16-17 Graduate Fellow

Department of Energy



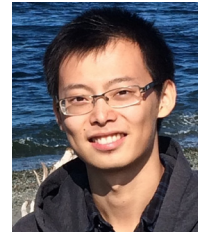
Shua Sanchez
PhD physics '21
'16-17 Graduate Fellow

Massachusetts
Institute of Technology



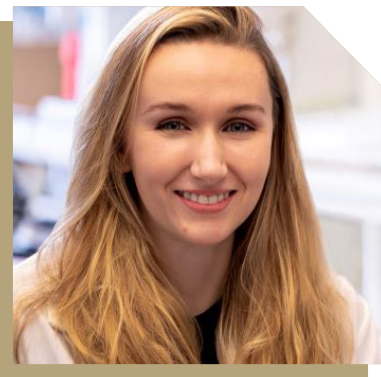
Yuanyuan Shi
PhD ECE '20
'16-17 Graduate Fellow

Assistant Professor,
University of California
San Diego



Bolun Xu
PhD ECE '18
'15-16 Graduate Fellow

Assistant Professor,
Columbia University



“CEI has helped me as a researcher in so many ways — with community, facilities and funding . . . I have relied heavily on the equipment and staff expertise available at the Washington Clean Energy Testbeds . . . to thoroughly characterize an enormous number of experiments in a short period of time. ”

-- Elizabeth Rasmussen, PhD Mechanical Engineering '21, CEI Graduate Fellow '18-19, National Institute of Standards & Technology

“CEI was critical to my graduate research, with a vibrant community of graduate students and faculty in clean energy materials, world-class instrumentation at my fingertips, and incredible opportunities to interface with utilities, innovators, and regulators in Washington state’s cleantech ecosystem as I developed my policy understanding and beliefs. ”

-- Sarah Vorpahl, PhD Chemistry '17, CEI Graduate Fellow '14-15, Rocky Mountain Institute



2021 - 2022 CEI GRADUATE FELLOWS

Chemistry

- Farhad Akrami
- Mark Bertolami
- Madeleine Breshears
- Tyson Carr
- Micaela Homer
- Austin Kamin
- Sebastian Krajewski
- Christine Morrison
- Nicole Panek
- Ramsess Quezada
- Ricardo Rivera-Maldonado
- Yangwei Shi
- Kathleen Snook
- Eden Tzanetopoulos
- Daniel Zhou

Chemical Engineering

- Karen Li
- Brenden Pelkie
- Duncan Reece

Civil & Environmental Engineering (CEE)

- Miguel González-Montijo

Electrical & Computer Engineering (ECE)

- Jiayi Li
- Xingyi Wang

Materials Science & Engineering (MSE)

- Diwash Dhakal
- Daphne Garcia
- Yifei He
- Xiaoxiao Jia
- Julia White

Mechanical Engineering (ME)

- Vinh Nguyen

Molecular Engineering

- Yuhuan Meng

Physics

- John Cenker
- Tharindu W. Fernando

Political Science

- Inhwan Ko



CEI Graduate Fellows at the 2022 Orcas Conference at the UW Friday Harbor Laboratories

ADVANCED EXPERIENCE PROGRAM

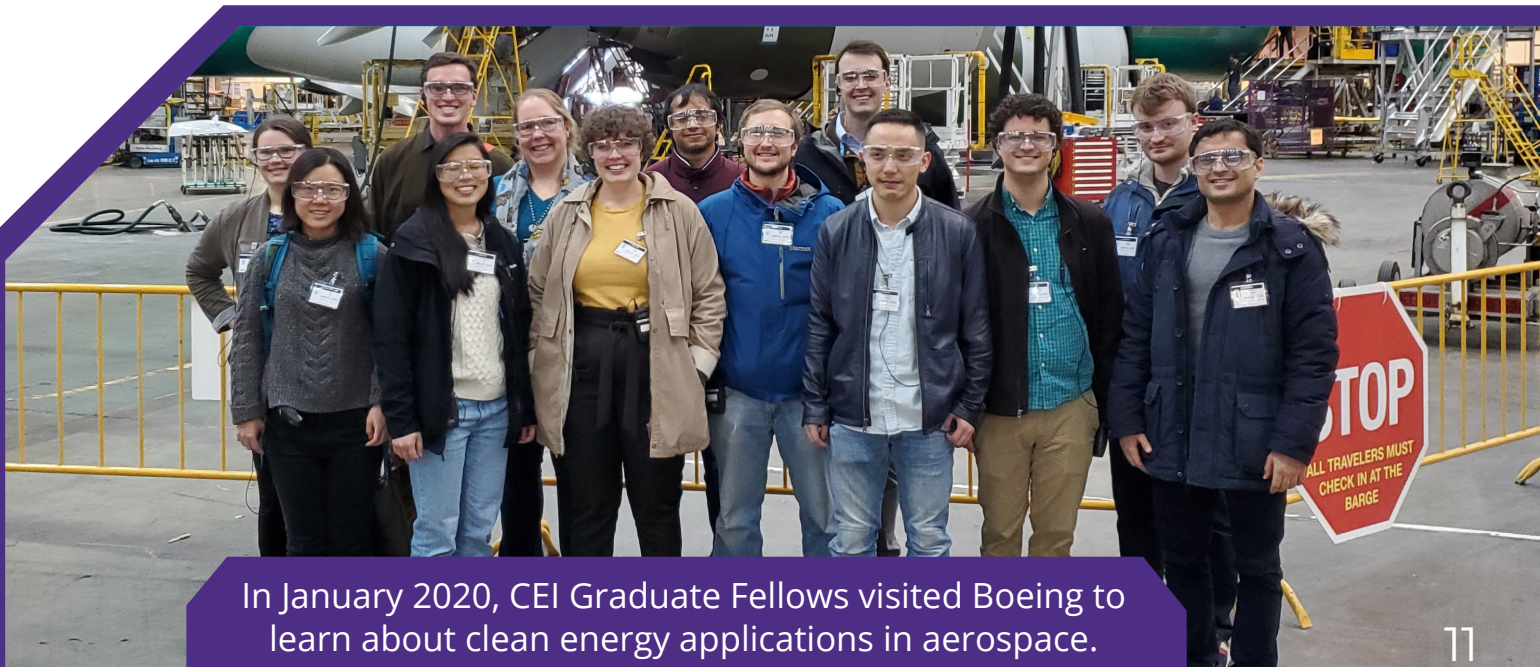
The Advanced Experience Program in Clean Energy (AXP), created through the generous support of the Mark Torrance Foundation, provides opportunities for UW doctoral students in STEM to apply their knowledge to support decision makers in clean energy investing and science policy. AXP is designed to be a flexible, 20-hour time commitment to complement each student's Ph.D. training and longer-term professional development. Torrance Tech Due Diligence analysts evaluate emerging climate technologies for the Seattle-area angel investing group E8; while Torrance Science Policy analysts prepare science and engineering briefs for policymakers alongside the Washington State Academy of Sciences. AXP has supported 47 Tech Due Diligence trainees since the 2017-18 academic year, along with 17 Science Policy Analysis trainees since 2020-21.

TRAVEL GRANTS

CEI Travel Grants cover up to \$1,500 in expenses for UW students conducting research in CEI-related areas to present their work at conferences — an ideal opportunity to apply science communication and networking skills. CEI has made a total of 200 travel grants in its history, averaging roughly 31 in years where travel was not restricted by COVID-19.

STUDENT HARDSHIP & OPPORTUNITY FUND

The CEI Student Hardship & Opportunity Fund helps students continue in PhD/ postdoctoral training when it may be otherwise challenging due to unmet financial burdens. Graduate students and postdoctoral researchers who are advised by CEI Member or Affiliate Faculty, or are able to demonstrate their involvement in the CEI community or broader CEI activities, may receive financial support in line with demonstrated need. The fund supported its first student in 2022.



In January 2020, CEI Graduate Fellows visited Boeing to learn about clean energy applications in aerospace.

EDUCATION & TRAINING FELLOWSHIP

CEI [Education & Training Fellows](#) (ETFs) work closely with CEI's education staff for two to four academic quarters to develop outreach activities, displays, and curricula for K-12 classrooms. They also arrange logistics and recruit CEI student volunteers for school outreach visits and other educational events.

2021 - 2022 Education & Training Fellows



Doris Hung
2020-2021 Graduate Fellow
Mechanical Engineering



Mitchell Kaiser
2020-2021 Graduate Fellow
Chemistry



“ I really believe the impact of our outreach is more than just a fun science lesson. When you ask a kid what they want to be when they grow up, they'll pick a career they know about, like sports or being a movie star. I want to show students what it's like to be a scientist and help make them comfortable with science, rather than scared of it. Their future is one in which clean energy is the main source of electricity, and any of them could be one of the scientists and engineers making it possible. ”

-- Erin Jedlicka, Chemistry PhD '21, 2018-19 CEI Education & Training Fellow

CLEAN ENERGY AMBASSADORS

[Clean Energy Ambassadors](#) are UW graduate and undergraduate students in STEM fields who lead students in hands-on activities at K-12 schools around Washington state and present at public events. The program is led by CEI ETFs and is open to any UW student aiming to give back to Washington state, hone their skills at communicating science to the public, or gain first-hand experience as a STEM educator. Ambassador activities include [solar car races](#), a “Meet a Scientist” presentation, and [lessons](#) including hands-on workshops on [mini solar panels](#) or [solar spinners](#). Through these activities, CEI seeks to inspire a new generation of diverse students to take up STEM careers to support the global transition to a clean energy economy.

CEI and its Clean Energy Ambassadors partnered with UW GEAR UP Achievers, a Department of Education program that provides support to middle- and high-school students from low-income families, to deliver a [virtual Clean Energy Summer Camp](#) in 2021. In addition, eight of the 20 outreach events during the 2021-22 school year were held at GEAR UP-affiliated South King County schools.

140 CEI graduate fellow
volunteer hours
in '21-22

1,600 K-12 students
reached in '21-22

1,270 Solar activity kits
sent to teachers and
librarians in WA

2 STEM fairs

2 Conferences

7 Virtual events

9 In-person events



CEI Education & Training Fellow Gabrielle Tosado (PhD Chemical Engineering '20) teaches students at Hazel Wolf K-8 School

SUMMER RESEARCH EXPERIENCES FOR UNDERGRADUATES & TEACHERS

In partnership with other UW units, industry partners, and nonprofit organizations, CEI provides students from non-R1 universities, minority-serving institutions, and community or technical colleges with opportunities to perform hands-on research and learn from UW clean energy experts.

Clean Energy Bridge to Research

Each summer, the Clean Energy Bridge to Research (CEBR) [Research Experience for Undergraduates](#) (REU) program provides a select group of 10-15 undergraduate, community college, and tribal college students with the opportunity to research solar energy, energy storage, grids and systems, and advanced energy materials under the mentorship of CEI faculty and student researchers. The CEBR REU is supported by the [UW Undergraduate Research Program](#) and funded by the National Science Foundation (NSF CHE-1950904). CEBR students embark on a nine-week immersive research project in a UW clean energy research lab, produce an abstract and poster summarizing their work, and present at the UW summer undergraduate research symposium. Participants receive a stipend, housing, food allowances, and a travel allowance.

77 REU students hosted in CEI labs since 2016



“Coming from community college, a lot of the little things about the experience really meant a lot to me. I loved living on my own and learning how to fit lab work in between cooking and grocery shopping, and I can't tell you how many times I got lost just walking around the city. The little gestures of support my fellow group members made for me had a tremendous impact, and I came away with confidence to become a chemical engineer.”

-- 2019 CEI REU Participant, Vanessa Zambrano, now a chemical engineering major at UC-Berkeley

Outstanding Undergraduate Research Award

CEI's new Outstanding Undergraduate Research (OUR) Award recognizes CEBR participants for exceptional undergraduate research and supports their continued journey in STEM fields. CEBR participants are nominated for this award by their graduate student mentors or their PIs. Awardees receive financial assistance of up to \$1,500 for a research conference of their choosing and the opportunity for another research experience in a UW CEI lab the following summer. The inaugural OUR awardees are:



Dina Chehada worked in chemistry professor Dianne Xiao's research group studying two-dimensional conductive metal-organic frameworks and their potential application as liquid crystals. After completing her Associate of Science degrees in Chemistry, Physics, and Mathematics from Cerritos Community College, she received a scholarship to pursue a Bachelor of Science in Chemistry at the University of California-San Diego.



Isabella Friedrichs researched single atom catalysts and clusters in chemistry professor Alexandra Velian's lab group, and returned to UW for a second REU in summer 2022. She will pursue a Ph.D. in chemistry after completing her undergraduate degree in chemistry and biology at Benedictine College.



Julisa Juarez worked in chemistry professor David Ginger's research group to study new perovskite semiconductors for solar energy applications, and returned to UW in summer 2022 to continue her project. After completing her degree in chemistry with a focus on environmental sustainability at Bennington College, she was accepted to UW Chemistry as a doctoral student in the Ginger Lab, earning a prestigious NSF Graduate Research Fellowship and an NSF Accelerating Quantum-Enabled Technologies Fellowship.

MSEP CEI ALVA

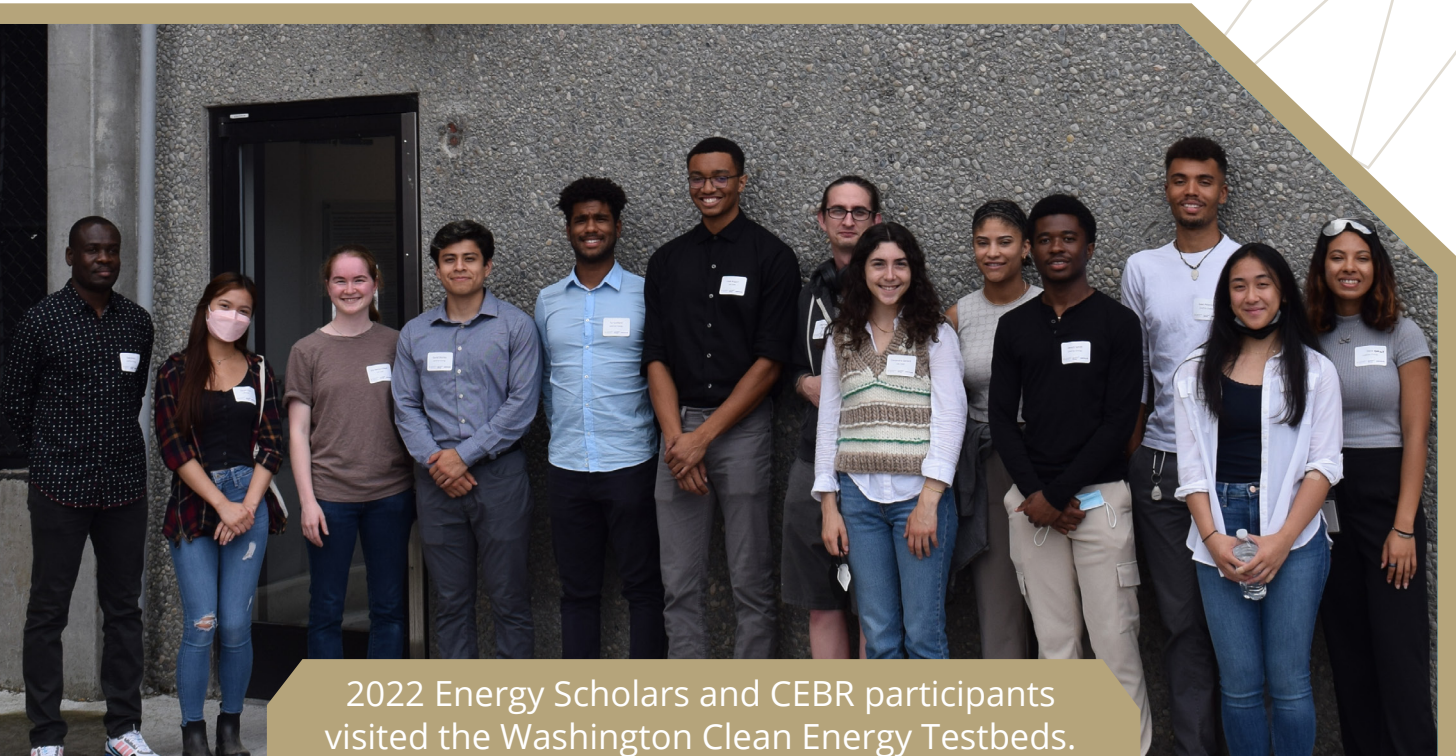
The University of Washington's Alliances for Learning and Vision for Underrepresented Americans (ALVA) program serves underrepresented students in a variety of disciplines for summer internships. In partnership with the [UW Minority Scholars Engineering Program](#) (MSEP) and the [Washington State Academic Redshirt](#) (STARS) program, CEI supports a summer research and enrichment ALVA program to promote retention and academic and professional excellence of early undergraduate students. CEI hosted 2 ALVA students in 2022, for a total of 25 since 2015.

Clean Energy Scholars Mentorship Program

Established in 2022 in partnership with UW EarthLab, the Clean Energy Scholars Mentorship program is a paid internship and mentorship program designed to equip dedicated and capable college scholars with the skills required to secure (and excel in) well-paid jobs in the renewable energy industry. The program progresses students through a well-defined, transdisciplinary curriculum spearheaded by industry-leading organizations. Energy Scholars attend seminars by CEI graduate student researchers and participate in professional development activities alongside CEBR REU students.

The 10 2022 Energy Scholars hailed from the following institutions:

- > Bennington College
- > Fisk University
- > Miami University
- > Texas Tech University
- > University of Texas at Dallas
- > University of Washington
- > Wesleyan University



2022 Energy Scholars and CEBR participants visited the Washington Clean Energy Testbeds.

Research Experience for Teachers

CEBR also supports the [Research Experience for Teachers \(RET\)](#) for local community college instructors who aim to integrate clean energy research into their curriculum. CEBR RET participants receive a stipend and spend six weeks in a CEI lab, where they learn a research technique and use it to develop a lesson for a two-year college with minimal equipment capability.

2022 RET participants

Anna Waschke

Northwest Indian College (NWIC)

Advised by UW ECE professor Baosen Zhang, Waschke researched the fundamentals of building a microgrid, and how wind and solar could be integrated into the electric grid. Waschke examined different types of wind turbines and the circumstances under which they would be optimal for deployment. Waschke's participation in the RET program follows that of Stephanie Bostwick, the founder of NWIC's engineering program, who investigated microgrids for education and energy sovereignty as a member of ECE professor Daniel Kirschen's research group in 2020.



Tommaso Vannelli

Whatcom Community College

Professor Vannelli worked with UW chemistry professor Cody Schlenker to design and synthesize advanced materials for heavy-atom-free solar photon upconversion. The technical goals of this project were to evaluate design strategies for new light-absorbing molecules with the potential to harvest energy from the sun that is not currently captured efficiently by existing solar photovoltaics. Vannelli's work will serve as the foundation for future curriculum development that leverages Course-based Undergraduate Research Experiences (CUREs) to provide community college students with exposure to authentic research experiences at their home institutions.



RESEARCH

OVERVIEW

CEI scientists and engineers are discovering new materials for more efficient, more easily-manufactured solar cells; designing new batteries that can safely power all forms of transportation or back up the electrical grid; and modernizing electrical grids with sophisticated information technology to accommodate new sources of power. Broadly, CEI research can be categorized within solar energy, energy storage, smart grids and systems integration, and advanced materials and basic science.

As an interdisciplinary institute, CEI enables UW faculty in several departments to leverage a range of research expertise, educational programs, and open-access, low-cost user facilities to attract federal grant support. CEI also serves as an experimental platform for UW faculty to develop new educational methods and facilities that support CEI's goals in education and training.

For instance, the new NSF Science and Technology Center (STC) for Integration of Modern Optoelectronic Materials on Demand (IMOD) templated its well-reviewed Quantum Leap Ambassadors program after CEI's Clean Energy Ambassadors, and its signature onboarding course after CEI's "Energy Materials Devices and Systems" (EMDS; see "Facilities") course. Likewise, UW's QuantumX Initiative this year opened the Quantum Technologies Training and Testbed Lab (QT3), a combined teaching and user facility for quantum information science and engineering that was inspired by, and directly modeled after, CEI's on-campus Research Training Testbed (RTT; see "Facilities").



CEI Member Faculty and Professor of Chemistry Brandi Cossairt with a student in the Research Training Testbed

RESEARCH CENTERS

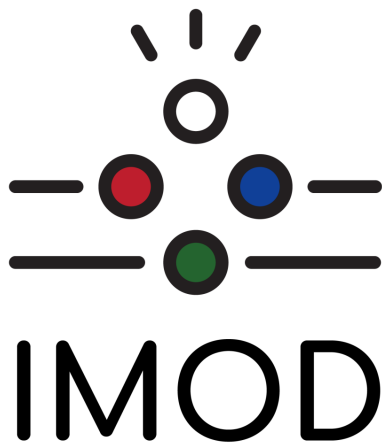
Led by CEI Member Faculty, these federally-funded research centers support a range of interdisciplinary activities under a major, cross-cutting research goal. These multi-institutional collaboratives typically include multiple R1 universities, startups and major corporations, and national laboratories.

Battery500 Consortium

[The Innovation Center for Battery500 Consortium](#) (Battery500) was [formed in 2016 with an initial \\$50M grant over five years](#) from the U.S. Department of Energy (DOE) Vehicle Technologies Office (VTO). Led by PNNL, Battery500 includes battery experts from UW, three additional national labs, and four universities, with IBM as an advisory board member.



Battery500 aims to develop next-generation electric vehicle batteries with a target energy density of 500 watt-hours per kilogram, a lifetime of 1,000 cycles, and a cost of less than \$100 per kilowatt. Battery500 director [Jun Liu](#) joined UW in 2019, and is now the Washington Research Foundation Innovation Chair in Clean Energy, the Campbell Chair Professor of materials science & engineering, and a professor of chemical engineering at UW while maintaining a Battelle fellowship at PNNL. In October 2021, [VTO awarded Battery500 an additional \\$75 million over 5 years for Phase 2 research activities.](#)



Center for Integration of Modern Optoelectronic Materials on Demand

The [Center for Integration of Modern Optoelectronic Materials on Demand](#) (IMOD) was established in September 2021 under a five-year, \$25 million Science and Technology Center (STC) grant from the National Science Foundation (NSF). The 11-university research collaborative is led by UW and directed by CEI chief scientist [David Ginger](#). IMOD research will center on new semiconductor materials and scalable manufacturing processes for new optoelectronic devices. Applications of IMOD research range from displays and sensors to [a technological revolution, under development today, that is based on harnessing the principles of quantum mechanics.](#)

Molecular Engineering Materials Center

[The UW Molecular Engineering Materials Center](#) (MEM-C), an NSF Materials Research Science and Engineering Center (MRSEC), is led by chemistry professor [Daniel Gamelin](#). It was established in September 2017 with an initial \$15.6M in funding over six years. MEM-C coordinates materials research between two colleges and five departments at UW and PNNL to address major trans-disciplinary challenges in materials research. Interdisciplinary research groups explore engineering defects in nanostructures for information processing, sensing, energy, and research tools, and the quantum properties of atomically layered materials. In autumn 2022, MEM-C leaders submitted a re-competition proposal for a second phase of NSF MRSEC activities.



U.S. Manufacturing of Advanced Perovskites Consortium



The [U.S. Manufacturing of Advanced Perovskites Consortium](#) (US-MAP) includes UW and its [Washington Clean Energy Testbeds](#) (see "Facilities"), the University of North Carolina at Chapel Hill, the

University of Toledo, the National Renewable Energy Laboratory (NREL), UW Chemistry spinout BlueDot Photonics, and other leading domestic solar companies. US-MAP was established [in May 2020](#) with the aim of accelerating the domestic commercialization of perovskite technologies. As a founding organizer, UW and the Testbeds serve on the US-MAP executive board and oversee delivery of projects. In April 2021, DOE's Solar Energy Technologies Office (SETO) [awarded \\$7.5M to two US-MAP projects](#) that leveraged the Testbeds in their proposals: \$2.5M to First Solar to develop a cost-competitive, high-yield, high-throughput manufacturing process for a 3,600 cm² solar cell with 22% power conversion efficiency (comparable to conventional silicon-based PV); and \$5M to a consortium that includes UW and NREL to establish the Center for Heuristic Evaluation of Emerging Technology Advancement (CHEETA), part of a joint perovskite bankability center led by Sandia National Laboratories.

RESEARCH HIGHLIGHTS

High-throughput and data driven strategies for the design of deep-eutectic solvent electrolytes

This paper, published in *Molecular Systems Design & Engineering* in May 2022, co-authored by CEI Graduate Fellows [Jaime Rodriguez](#) and [Maria Politi](#), details the use of cheminformatics and liquid-handling robots to rapidly identify, synthesize, and characterize 600 combinations of molecules that could exhibit desirable physical and electrochemical properties, such as those of a battery electrolyte. This automated technique is open source, and is broadly applicable within large materials design spaces. Senior author [Lilo D. Pozzo](#) — CEI Member Faculty, the Boeing-Roundhill Professor for Excellence in Chemical Engineering, and professor and interim department chair of materials science & engineering — advises UW spinouts such as Membrion, and has been recognized for outstanding achievement in education and mentorship by UW Engineering and the DOE Clean Energy Education and Empowerment (C3E) Initiative.

Improving Public-Private Partnerships for Renewable Electricity Infrastructure in Lower- and Middle-Income Countries

This analysis of nearly 1,800 high-capital cost clean energy projects, published in the *Journal of Construction Engineering and Management* in February 2022, showed higher success rates than expected for PPPs that included a purchase agreement as the primary revenue stream, but lower success rates for PPPs that included a competitive bid process. While further investigation is prompted, these results may help public agencies choose between types of PPPs (Brownfield, Greenfield, or a management and lease contract) or how to award a contract and select a primary revenue stream when a PPP is moving forward, as over \$3.5 billion in project funding was written off across the data set. Author [Jessica Kaminsky](#), an associate professor of civil & environmental engineering and CEI Affiliate Member Faculty, is a leading researcher in socially-sustainable civil infrastructure. In 2021, she was recognized by the American Society of Civil Engineers (ASCE) with the Halpin Award for Scholarship in Construction.

[Light-induced ferromagnetism in moiré superlattices](#)

This April 2022 Nature paper authored by UW postdoc [Xi Wang](#), a member of UW physics professor [Xiaodong Xu's research group](#), describes the revolutionary use of lasers to align the spins of electrons within sheets of semiconductors just three atoms thick, thereby triggering a form of magnetism in an otherwise non-magnetic material. The ability to control the fundamental properties of electrons using light is considered to be vital for the future construction of quantum computers, which may use electrons and their range of possible spins to encode and manipulate information with speed and power far beyond the theoretical limits of classical computers and the 1s and 0s of their on-off transistors. Co-senior author Xu, who is one of CEI's Member Faculty, has been consistently named to Web of Science's international list of Highly Cited Researchers. [Read more in the April 2022 UW News article, "Lasers trigger magnetism in atomically thin quantum materials."](#)

[Lower limits for non-radiative recombination loss in organic donor/acceptor complexes](#)

The graduate thesis of CEI Graduate Fellow [Yun \(Demi\) Liu](#) (advised by [David Ginger](#)), this May 2022 Materials Horizons paper describes a new blend of organic, charge-transferring materials that exhibits a significant reduction in energy losses due to non-radiative recombination: essentially, the fraction of activated electrons that release their excess energy into the lattice of the material instead of emitting a photon or flowing out as current. This development may boost efficiencies in both luminescent devices like light-emitting diodes (LEDs) that convert electricity into light, as well as photovoltaic solar cells that convert light to electricity. Liu's thesis received the UW Department of Chemistry's 2021-22 award for best thesis in physical chemistry.

[Modeling Current Density Non-Uniformities to Understand High-Rate Limitations in 3D Interdigitated Lithium-ion Batteries](#)

This October 2021 J. Electrochem. Soc. paper, first-authored by CEI Graduate Fellow [Chih Hsuan \(Doris\) Hung](#), is a computational analysis of four battery designs that each utilize an intertwined anode and cathode, instead of flat layers, to improve performance during fast charge and discharge cycles. Senior author [Corie Cobb](#), CEI Member Faculty, Washington Research Foundation Innovation Professor of Clean Energy and professor of mechanical engineering, is a national leader in advanced manufacturing and energy storage. Cobb holds 20 US patents in 3D Lithium-ion batteries, 3D printing and high-precision manufacturing, and recently won a prestigious DARPA Director's Fellowship to continue her DARPA Young Faculty Award research in additively-manufactured batteries.

COLLABORATIVE SEED GRANTS

Established in March 2022, CEI [Collaborative Seed Grants](#) provide teams of UW PIs with up to \$100,000 in funding to pursue large, center-scale, team-based proposals to transform clean energy science and technology. Collaborative Seed Grants provide UW scholars the freedom to explore novel, high-risk/high-reward research topics while seeding new collaborations in research and education that raise the profile of CEI in ways that significantly increase the prospects of future support via specific extramural grant, such as STC, NRT, or MRSEC. Three Collaborative Seed Grants were awarded in FY22:

Inverted Aqueous Zinc-Ion Batteries

While lithium-ion batteries (LIBs) are ubiquitous in modern consumer electronics and electric vehicles thanks to their high energy density and well-understood chemistry, their reliance on scarce lithium metal and flammable organic electrolytes means that alternative designs may find a foothold in applications like long-term, grid-scale storage or wearable electronics. Aqueous zinc-ion batteries (ZIBs) are a particularly attractive alternative thanks to low-cost, non-toxic, simple, and mature processing, but their development has been limited by the lack of high-performance cathodes and fundamental understanding of the more complex ion-storage chemistry.

[Samson A. Jenekhe](#) (chemical engineering, chemistry) and [Guozhong Cao](#) (MSE) aim to demonstrate an “inverted” ZIB that uses zinc metal as the cathode instead of the anode, which they believe may minimize or eliminate operational deficiencies related to conventional ZIB electrochemistry. The PIs will explore various novel materials as possible anodes, including a semiconducting organic polymer, a layered vanadium oxide, and complex oxides that contain at least five different transition metals. The data generated under the seed grant will enable the formulation of major hypotheses to drive external grant proposals. In the long run, the team aims to add 2-3 PIs and compete for external funding from programs such as NSF’s MRG and ERC, ARPA-E, industry consortiums, and MURI.

Integrated Design, Evaluation, & Automation of Materials for Advanced Photonics (IDEA-MAP)

PI [Cody Schlenker](#) (chemistry) and co-PIs [Lilo Pozzo](#) (chemical engineering, MSE), [Matthew Golder](#) (chemistry), [Munira Khalil](#) (chemistry), [Sotiris Xantheas](#) (chemistry via PNNL), and [Xiaosong Li](#) (chemistry) will integrate computational chemistry, machine learning, spectroscopy, automated chemical synthesis, and high-throughput screening to develop new molecules for near-infrared (NIR) photon upconversion in next-generation solar photovoltaics. This “fusing” of solar NIR light into visible light that can be harvested by today’s PV modules could boost power conversion efficiencies by more than 10%; analysts suggest that if upconversion can be achieved at 1% of PV module cost, it could revolutionize the \$100 billion global solar market.

The team will use initial results to apply for NSF [Designing Materials to Revolutionize and Engineer our Future](#) (DMREF) funding in 2023, with a longer-term goal of securing broader MURI and center-level funding for Integrated Design, Evaluation, & Automation of Materials for Advanced Photonics (IDEA-MAP) and other clean energy technology initiatives, e.g., in batteries. The team also plans to interface with community and tribal colleges, developing Course-based Undergraduate Research Experiences (CUREs) in Chemistry, Engineering, and Robotics.

Moiré superlattices boosted hydrogen evolution reaction

The U.S. Department of Energy [recently announced billions of dollars in funding for Hydrogen Hubs via the 2021 Bipartisan Infrastructure Law](#), which emphasized hydrogen as a critical part in the comprehensive energy portfolio of the United States.

[Xiaodong Xu](#) (physics) and [Jihui Yang](#) (MSE) will study the possible use of two-dimensional semiconductors as an efficient alternative to precious metals in electrocatalysts for hydrogen fuel cells. The PIs have previously demonstrated the ability to layer these atomically-thin materials with a relative twist, resulting in the formation of a “Moiré superlattice” across the layers with highly tunable electronic properties. The PIs have also developed spectroscopic techniques to analyze the performance of the Moiré superlattice materials in the hydrogen evolution reaction. The team aims to apply for a DOE EFRC award in 2024.

FACILITIES

WASHINGTON CLEAN ENERGY TESTBEDS

CEI opened the [Washington Clean Energy Testbeds](#) in 2017 to provide academic and industry researchers with state-of-the-art capabilities for full-cycle development of climate technologies, including prototyping, testing, scaling, and validating new materials, devices, and software tools. The lab facility, which currently occupies about 16,000 square feet of leased space near UW, is a unique public venue for innovation and demonstration that offers pay-as-you-go, open access to users without impacting their intellectual property.

Testbeds staff scientists and engineers provide customized, hands-on training on each instrument and can also perform contract-based remote work. The staff have experience in relevant sectors including power electronics, climate tech, clean energy, and mass production.

Unique Testbeds instruments include:

- Modular, multi-functional, roll-to-roll processing line
- Multi-nozzle ultra-high resolution ink jet printer capable of nano-scale additive manufacturing
- Controlled environment manufacturing lab
- Real-time digital simulator that allows users to test software and hardware “in the loop” instead of independently developing their own testing platform.



Washington Clean Energy Testbeds technical director J. Devin MacKenzie demonstrates the Testbeds' roll-to-roll printer for solar and other electronic devices.

WASHINGTON CLEAN ENERGY TESTBEDS RESOURCES

Testbeds Experts-in-Residence advise entrepreneurs and early-stage climate tech startups at free, weekly office hours, and hosts workshops and events.

The Testbeds **Entrepreneur-in-Residence (EIR)** advises companies on team formation, product development, strategic marketing, fundraising, manufacturing strategy, and business development.



The Testbeds EIR [Dr. Thomas Madden](#) is the chief technology officer at Advanced Cell Engineering. Previously, Madden was the Principal at Madden Echem Concepts, CTO at BenAn Energy and Aquion Energy, and led energy storage stack development at Lockheed Martin Advanced Energy Storage and UTC Power. Madden is an affiliate professor of chemical engineering at UW, from where he received his PhD in chemical engineering, and serves as a Proposal Reviewer for DOE EERE and ARPA-E funding solicitations and as a Merit Reviewer for DOE EERE programs.

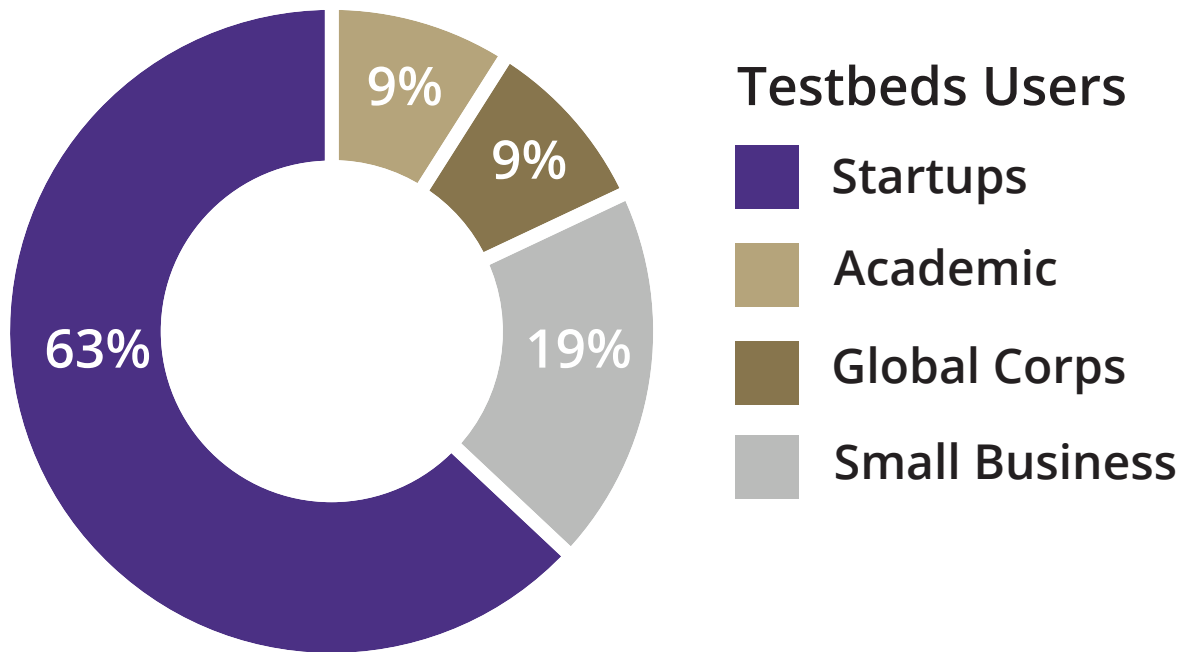
Previous EIRs include [Ben Bierman](#) (member, E8 Angels), [Scott Case](#) (Co-Founder and CEO, Recurrent), [Ramkumar Krishnan](#) (technical advisory board, BattGenie), and [John Plaza](#) (President and CEO, SkyNRG Americas).

The Testbeds **Investor in Residence (IIR)**, established in partnership with cleantech-oriented angel investment group E8, consults on funding proposals, investor pitches, financial strategy, fundraising, and strategic partnerships.

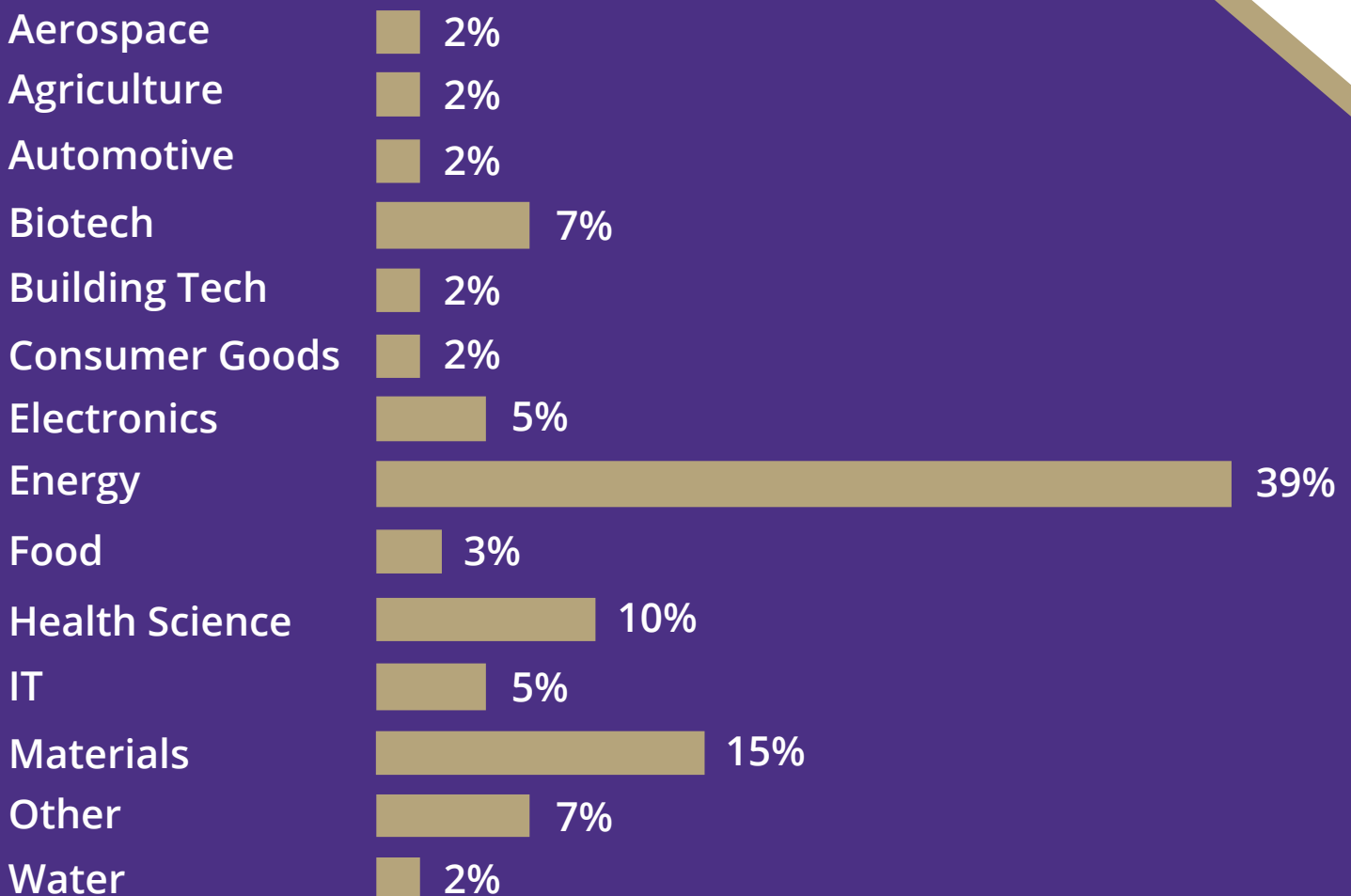


Testbeds IIR [Jeff Canin](#) is a member of the Board of Directors at [E8](#) and a co-manager of E8's venture fund. Jeff's career includes extensive experience in financial services and venture capital. His current efforts are focused on providing advisory services to early-stage companies and university technology commercialization spinouts.

The Testbeds welcomed 135 new users in FY22, including from 53 companies and six universities, with an average of 64 unique users working at the Testbeds each month. About 50% of FY22 Testbeds users hailed from industry, with the energy and materials sectors accounting for 55% of those users.



Testbeds Users by Sector



FY22 User Highlights

- > **BattGenie** partnered with Two Rivers Community Development Corporation for second-life deployment of EV batteries, and were one of five companies selected by the National Renewable Energy Lab for the Shell GCxN Accelerator.
- > **WhyGrene** completed work on their power systems management app at the Testbeds, which resulted in a contract with San Diego Gas & Electric; and were accepted into TechStars.
- > **florrent** joined Greentown Labs to develop hemp-based ultracapacitors for next-generation energy storage.
- > **Leap PV** reached the final round of the American-Made Solar Prize with their advanced manufacturing process.

CleanTech Hardware Innovation Prototyping (CHIP) Program

Established in partnership with the Seattle-based nonprofit [CleanTech Alliance](#) and [VertueLab](#), a Portland, OR-based nonprofit that supports climate entrepreneurs, the CleanTech Hardware Innovation Prototyping (CHIP) program provides three to six early-stage climate tech companies with \$10k-\$30k worth of Testbeds access over six months for scaled prototyping, testing, and/or demonstration activities that would otherwise be unaffordable. CHIP aims to enable companies to advance one technology readiness level and establish a foundation for more significant follow-on funding from grants or investors.

The first cohort of companies began CHIP-supported work at the Testbeds in March 2022:

- > **Aquagga** used the Research Training and Scale-Up & Characterization Testbeds to design and test a reactor that breaks down toxic per- and polyfluoroalkyls (PFAs), and to develop and prototype upgraded reactor designs.
- > **StorEdge AI** used the Systems Integration Testbed to build and evaluate the performance of a non-wired grid-forming inverter for remote solar + storage deployments.
- > **Vizi Metering** used the Systems Integration Testbed to support its first full deployment of wireless voltage meters and to establish energy efficiency protocols for facilities based on meter data.

RESEARCH TRAINING TESTBED

Part of the Washington Clean Energy Testbeds system, the Research Training Testbed (RTT) provides UW students access to industrial-quality research tools and training in clean energy concepts that cut across academic disciplines. Located on the 1st floor of the Nanoengineering and Sciences Building, the lab is open to UW research groups as well as students interested in developing and testing their climate tech prototypes.

Energy Materials, Devices, & Systems Course

CEI Member Faculty created a hands-on course housed in the RTT to train students across the scales of clean energy. In “Energy Materials, Devices & Systems” (EMDS), upper-division undergraduates and graduate students get project-based training on materials for energy generation and storage, and the integration of renewables into energy systems. EMDS currently welcomes 30 UW students from across the College of Arts & Sciences and the College of Engineering each year. EMDS students learn a wide breadth of energy research techniques including:

- > Nanoparticle synthesis and characterization (CdSe quantum dots)
- > Solar photochemistry – hydrogen fuel production
- > Batteries – fabrication and testing of Li-ion coin cell with carbon electrodes
- > Photovoltaics – third generation solar cell fabrication and characterization (organic-PVs and perovskites)
- > Semiconductor properties – 2D material fabrication and testing
- > Grid simulation



EMDS TA Malia Steward (left), a mechanical engineering doctoral student, assists an EMDS student to characterize the performance of a solar cell, fabricated in the RTT.

A NEW BUILDING FOCUSED ON SOLUTIONS FOR A HEALTHY PLANET

In January 2018, the Washington State Legislature allocated \$20M to the University of Washington to establish a world-class center for advanced materials and clean energy technologies, or CAMCET.

As part of the [2019 Campus Master Plan](#), UW and City of Seattle leaders approved nearly 3 million square feet of new development in the area to the west of the main Seattle campus, on the south end of the University District neighborhood. This new development is now known as Portage Bay Crossing.

In March 2022, after a pause to address urgent pandemic needs, the [UW Board of Regents approved the project plan](#) for the first major development within Portage Bay Crossing: a new, 11-story, 340,000-square-foot building focused on solutions for a healthy planet. This building will be located at Site W27, between NE 40th Street and the Burke-Gilman Trail, with University Way NE (“the Ave”) to the east and Brooklyn Avenue NE to the west. The W27 building will include space for UW research and education, as well as market-rate leasable spaces for UW mission-aligned partners. [Wexford Science + Technology](#) was selected to [develop and manage](#) the building and recruit external tenants.

CAMCET, including the Washington Clean Energy Testbeds, will occupy more than 30,000 of the 130,000 square feet allocated to UW within the W27 building, which is estimated to be completed in Spring 2025. This doubling of the Testbeds’ footprint will expand fabrication capabilities, including advanced manufacturing of pouch cell batteries, and will create dedicated spaces for testing solar, batteries, and other materials, private user R&D activities, community engagement, and events.



A rendering of the new building at Site W27 in Portage Bay Crossing, the future home of the Testbeds. Credit: ZGF Architects

EXPANDING CEI WITH STATE SUPPORT

Thanks to new state funding, the Clean Energy Institute is growing to support areas of national need where Washington state can lead. For example, CEI is expanding battery-related infrastructure and training programs to align with the state's demand for people and ideas that fuel innovation in battery materials and manufacturing. This growth complements Washington's major new federal funding and private capital to grow U.S. battery supply chains. Washington-based Group14 (co-founded by CEI TAC member Rick Luebbe) and Sila Nanotechnologies (a California-based company) each received \$100 million via the federal Bipartisan Infrastructure Law, augmented by more than \$500 million dollars of private investment, to construct battery materials processing plants near Moses Lake, WA. The demand for innovative ideas and talented battery scientists and engineers will continue to rise in Washington, and new investments help CEI keep pace with this demand.

Another priority for state and federal policy is investing in clean energy projects that bring lower emissions, lower energy costs, new employment opportunities, and greater resiliency to disadvantaged communities. New state funds are helping CEI strengthen community ties by expanding our K-14 STEM educational programs and adding new technical assistance programs. CEI has a scalable model for supporting student design teams, research teams, and professional staff who can work directly with communities and community-based organizations to assess the impact of traditional fossil energy on community health and to design clean energy systems that meet community goals. To expand university expertise in community-engaged energy research and training, CEI has helped the colleges of engineering and built environments hire new faculty with expertise in community-scale energy infrastructure planning and design. As a neutral, trusted source of interdisciplinary technical, economic, and environmental analysis, UW is uniquely positioned to bring creative ideas and design strategies for equitable implementation of state and federal climate policies.

NEW CLEAN ENERGY FACULTY SUPPORTED BY CEI



[June Lukuyu](#), assistant professor of electrical & computer engineering, researches technology-driven strategies to improve energy development, electrification and energy systems planning in underserved regions.



[Julie Rorrer](#), assistant professor of chemical engineering, develops catalysts for waste plastic upcycling and other sustainable methods of chemical production. CEI is funding a postdoctoral researcher to support **[ColorMePhD](#)**, an outreach initiative founded by Rorrer that uses coloring pages to communicate Ph.D.-level STEM research to a broad audience.



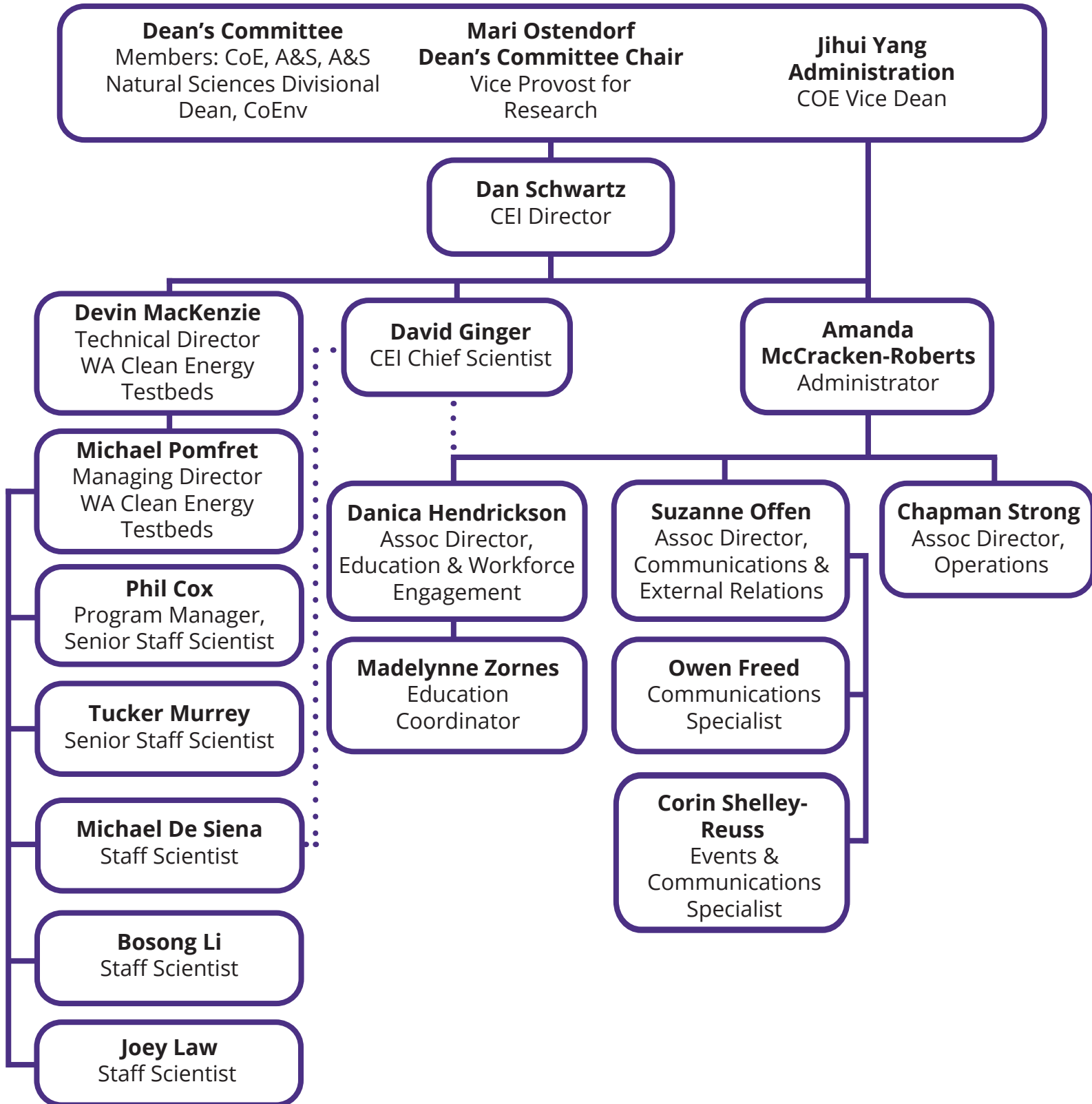
[Dylan Stevenson](#), incoming assistant professor of urban design and planning, investigates the integration of Indigenous knowledge and cultural values with environmental stewardship.

EXPENDITURES OVERVIEW

	FY 20	FY 21	FY 22
Research Investments	\$1,760,582	\$970,037	\$1,651,426
Education & Workforce Engagement	\$837,000	\$1,150,870	\$1,034,617
Shared Capital Equipment	\$2,500,000	-	-
Faculty Support (Salary + Startup)	\$558,810	\$603,903	\$585,951
Staff & Operations	\$311,800	\$442,500	\$681,417
Student & Postdoctoral Support	\$501,136	\$380,541	\$469,459
Total	\$6,469,328	\$3,547,851	\$4,422,870

APPENDIX 1

CEI ORGANIZATIONAL CHART



APPENDIX 2

TRAINEE & FACULTY ADVISORY BOARD



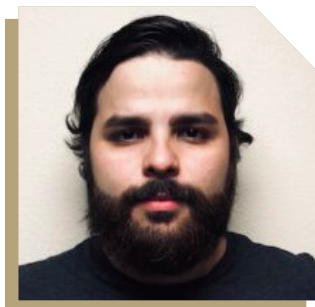
Brandi Cossairt
Professor of
Chemistry



Daniel Gamelin
Professor of
Chemistry



David Ginger
TFAB Chair
Professor of
Chemistry



Miguel Gonzalez
CEI Graduate Fellow
& PhD candidate in
Civil & Environmental
Engineering



Danica Hendrickson
Associate Director
of Education
& Workforce
Engagement



J. Devin MacKenzie
Professor of Materials
Science & Engineering,
Mechanical
Engineering



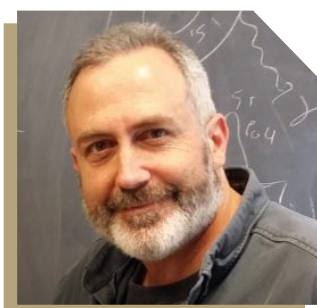
Emily Nishiwaku
CEI Graduate Fellow
& PhD candidate in
Chemistry



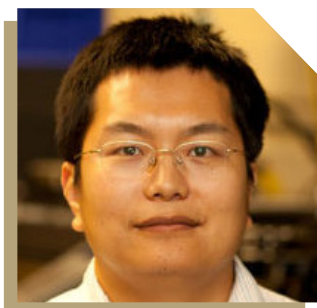
Lilo Pozzo
Interim Chair of
Materials Science
& Engineering,
Professor of Chemical
Engineering



Cody Schlenker
Professor of
Chemistry



Jerry Seidler
Professor of Physics



Xiaodong Xu
Professor of Physics
and Materials Science
& Engineering



Baosen Zhang
Professor of Electrical
& Computer
Engineering

APPENDIX 3

CEI TECH ADVISORY COUNCIL

David Benson, Partner, K&L Gates

Susan Betcher, Partner, Firmwide Co-Chair, Cleantech Industry Practice Group, Perkins Coie, LLP

Katy Briggs, Global Service Area Leader, Renewables Advisory, DNV GL – Energy

Jeff Canin, Board Member & Fund Manager, E8

Byron Crawford, Northwest Power BD Lead, HDR

Dave Curry, Chairman & CEO, Demand Energy Networks, Inc

Renee Gastineau, Business Solutions Director, ENGIE Impact

Craig Husa, Director, Lockheed Martin Energy

Jamie Johnson, Associate, Perkins Coie

Curt Kirkeby, Technology Strategist, Avista Utilities

Vijay Kumar, Associate, Perkins Coie

Jun Liu, WRF Innovation Chair in Clean Energy and Campbell Chair Professor, Materials Science & Engineering, Chemical Engineering

Rick Luebbe, CEO & Co-Founder, Group14 Technologies

Daniel Malarkey, Senior Fellow, Sightline Institute

Uzma Siddiqi, Technology Principal Engineer, Seattle City Light

Ben Straughan, Partner, Emerging Companies & Venture Capital, Perkins Coie, LLP

Lawrence Tsang, Project Executive and VP of Strategy, Convergent Energy + Power

Tess Williams, Co-Founder & Principal, Sound Grid Partners

Malcolm Witter, Director, Dean Witter Foundation

APPENDIX 4

DEAN'S COMMITTEE



Nancy Allbritton
Dean of the College
of Engineering



Dianne Harris
Dean of the College of
Arts and Sciences



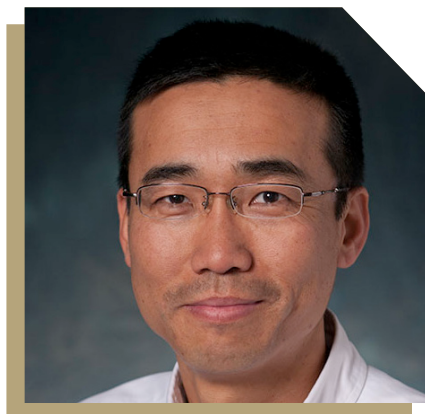
Mari Ostendorf
Chair, UW Vice Provost
of Research



Dan Pollack
Divisional Dean of Natural Sciences,
College of Arts and Sciences



Maya Tolstoy
Dean of the College
of the Environment



Jihui Yang
Vice Dean of the
College of Engineering