CLEAN ENERGY INSTITUTE

UNIVERSITY of WASHINGTON

2014 ANNUAL REPORT

January 2015

Message from the Director

2013 – 2014 Highlights

- Attracted **$6.74 million** gift from Washington Research Foundation (WRF) to accelerate our ability to attract talent to the state
- Hosted Governor Inslee, staff, and community members at 2013 Kickoff Event
- Launched a successful faculty hiring campaign in Advanced Materials for Energy and Energy Systems & Integration research areas and partnered with UW colleges, WRF, PNNL to hire **four new clean energy faculty**
- Contributed to the education of more than **53 STEM scholars** through Graduate Fellowship and Student Training & Exploration Grant Programs
- Established the **WRF Innovation Fellows Program** to help attract the next generation of innovation leaders in solar energy conversion, energy storage, and grid integration technologies to the UW
- Helped the UW acquire **14 major new instruments valued at more than $5 million** by leveraging $1.53 million of CEI funds
- Supported **tech translation projects** across the state through the Center for Commercialization and the Buerk Center for Entrepreneurship

Dear Friends of the Clean Energy Institute,

It has been an exciting and busy time since we launched the Clean Energy Institute in 2013. Our focus has been on the ideas, people, innovations, and partnerships needed to advance the next generation of scalable clean energy technologies.

The clean energy economy is growing quickly. Over the next twenty years, global investment in new energy generation is projected to be $9.7 trillion, with 71 percent of those dollars invested in low carbon technologies according to Citi Research. Over the same period, global investment in the grid is projected to be about $7 trillion. Our state has been a global leader in clean energy production and grid technologies for the last seven decades. The Clean Energy Institute is forging the ideas, people, innovations, and partnerships that will disrupt energy generation, storage, and grid technologies for decades into the future, ensuring our state is positioned to meet this global demand.

A clean energy future that can scale to meet global demand will be founded on new materials and devices that capture and store more of the abundant solar energy that streams down on every corner of our planet. But to be disruptive, scientific breakthrough must be mated to engineering innovations in device design and manufacturing that keep costs down. At the same time, cost-effective and reliable energy requires advances in the way information technology is used to control an infinitely more complex system that has many individuals, businesses, and communities as producers or consumers of energy at different times each day. Our faculty, students, and partners are focused on the scientific breakthroughs and engineering innovations that will ensure our state's leadership in these areas.

Since our founding in 2013, the Institute's faculty have attracted more than $30 million dollars of funding to help us achieve our goals. These funds come from diverse sources, including roughly $6 million of core state funds, $9 million of new private gifts or industry grants, and $15 million of new federal grant funding. We have also established important research and industry partnerships across the region, and have added four new faculty who augment our campus and regional strengths.

Students and other young scholars are central to our search for solutions in clean energy. In fact, supporting young scholars in diverse STEM fields is our largest single use of the $30 million in funds we receive. State funding to CEI is purposeful in its focus on forging interdisciplinary leaders in clean energy research who understand the energy marketplace. At the UW, we know 74 percent of our graduates end up living in the State, and that makes us confident that CEI's investment in 60 CEI graduate and research fellows is laying the foundation for the state's clean energy leaders in 2035. Finally, CEI graduate fellows are active in outreach that sparks the interest of K-12 students in STEM education and helps them imagine a future where they become UW graduate fellows of tomorrow.

Thank you for your support to date. We look forward to your continued support in the coming years as we grow the Clean Energy Institute.

Sincerely,

Daniel T. Schwartz
Director, Clean Energy Institute
Boeing-Sutter Professor of Chemical Engineering
University of Washington

Advancing the next generation of solar energy and electrical energy storage materials, devices and integrated systems

Spotlight on the Clean Energy Institute

Our Vision

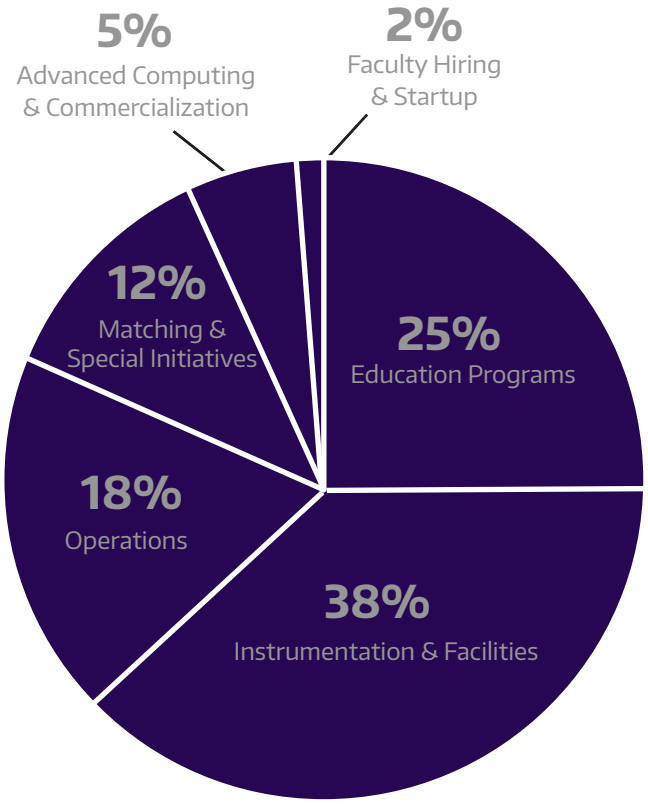
The Clean Energy Institute is advancing the next generation of solar energy and electrical energy storage materials, devices and integrated systems.

We are accomplishing this vision through scientific and engineering research combined with partnerships that leverage eight decades of unique clean energy leadership, knowledge, and infrastructure in our state and region.

CEI is organized among research areas in Advanced Materials for Energy and Energy Systems and Integration which spans materials research, energy storage and includes electrical grid integration.

Financial Overview

$6 Million Total Biennial State Funding (FY14 and FY15)



- With key support from the Washington Research Foundation (WRF) supported the hiring of **two world-class clean energy faculty** at the UW
- Provided seed funding and matching funds leading to the **award of $1.5 million from the Department of Energy Sunshot Program**
- Provided **Research Assistantships for 53 graduate students** through Graduate Fellowship Program and Student Training & Exploration Grant Program
- Helped the UW acquire **14 major new instruments valued at more than $5 million** by leveraging $1.53 million in CEI funds
- Provided clean energy **prototype funding for Washington students** through the Buerk Center for Entrepreneurship's Environmental Innovation Challenge
- Established shared operations and staffing with the Molecular Engineering & Sciences Institute

Establishing Key Partnerships Across the State

- Established important research, community and industry partnerships with Pacific Northwest National Laboratory, Clean Technology Alliance of WA, Smart Grid NW, State SmartGrid Grant Team, UET, 1Energy Systems, EnerG2, SnoPUD, Alstom Grid, and an external CEI Advisory Council
- Hosted high-profile events such as the CEI Launch Event with Governor Inslee (December 2013), CEI Research Showcase with state legislators and staff (September 2014), Seattle Chamber of Commerce Leadership Retreat (October 2014), College of Engineering Visiting Committee meeting (November 2014), and U.S. Office of Naval Research (December 2014)
- Provided sponsorship and prototype funding to support the UW Buerk Center's Environmental Innovation Challenge
- Faculty, students, and staff participated broadly in outreach activities to build community support, engage the public and educate students from K-12 up to college levels

A Growing Partnership: SnoPud, PNNL, 1EnergySystems, and the UW showcased the new grid integrated battery in Everett, WA in early 2015 (see Research Highlight below)

Research Highlight: Energy Systems & Integration

Washington Makes Large Investment In Renewable Energy Storage and Grid Integration

The Clean Energy Institute is a participant in a major state initiative that will look to store renewable energy and feed it to the grid during peak demand times. The project is partly funded by the state's Clean Energy Fund, which is providing $14.3 million in matching funds for three projects that will integrate power generated from intermittent renewable sources, such as wind and solar, in the state's electrical grid. The project involves three of the state's major utilities and its research institutions, including the Pacific Northwest National Laboratories (PNNL) and the University of Washington Clean Energy Institute. In January 2015 large battery systems were placed in test sites in Pullman, Washington and in Everett, Washington with more to follow.

Professor Daniel Kirschen, a CEI faculty member and professor of electrical engineering, will participate in the utility demonstration projects working alongside PNNL. Using data collected by PNNL, Kirschen will be assessing the economic value that these batteries create in the electrical grid as a function of various technical parameters such as the battery power rating, energy rating, location, and how the battery and storage is being used in the individual demonstration projects. Using this data, the team can then draw conclusions about the long term value for larger scale deployment of the batteries and energy storage applications in Washington state and beyond.

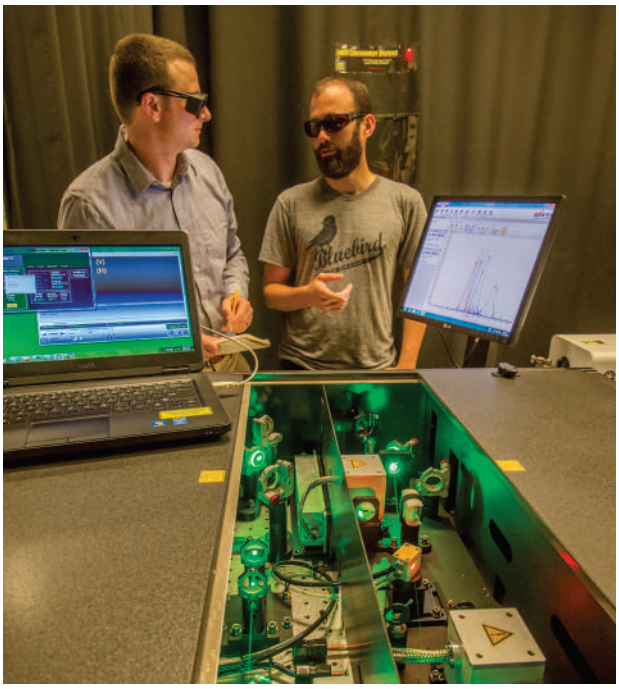
Washington Research FOUNDATION

A Transformational Gift from the Washington Research Foundation

The Washington Research Foundation will provide CEI with $6.7 million over six years to support nine new faculty members who will focus on the cost and increasing the performance of solar energy production, storage and delivery. Research will include the discovery of advanced materials for solar cells and batteries, manufacturing methods that are lower cost, and the development of new software and hardware strategies for integrating clean energy with systems and the grid. The funding will also support 6 new postdoctoral researchers and the creation of a new experimental manufacturing facility on campus that will help move discoveries from the laboratory to the marketplace.

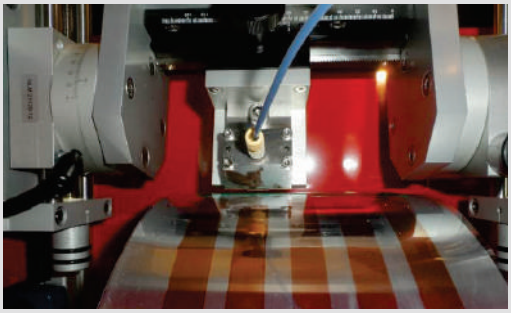
Making Smart Investments

- Helped the UW acquire 14 major new instruments valued at more than $5 million by leveraging $1.53 million of matching CEI funding – such as a $600 thousand ultrafast laser funded by the Office of Naval Research with $125 thousand CEI cost share
- Leveraged faculty startup funds to establish a shared battery development and testing facility that will be benefit researchers across campus and serve as a recruitment tool for upcoming faculty hires in battery materials
- Partnered with the UW Molecular Engineering & Sciences Institute to build up its staffed instrumentation facility in order to provide needed resources for broad use of the clean energy research community on campus and across the region



Did you know? During this period, the UW Clean Energy Institute printed its first large area solar cells in the new roll-to-roll printing laboratory established in Roberts Hall (see Research Highlight below).

Research Highlight: Advanced Materials for Energy



Photovoltaic inks are use to print solar cells on a bench-top roll-to-roll coater at the UW

The Next Revolution in Solar Energy: High Efficiency Printable Tandem Solar Cells

The cost of electricity from new solar cell installations is starting to compete with electricity from new coal and nuclear plants in sunny locations. Thanks to research at the University of Washington, the solar cells of the near future might be printed from inks and reach efficiencies more than double that of today's typical solar cells, reducing the cost of electricity to below the level of even natural gas, the cheapest fossil fuel available now. They may even be able to compete with the low cost electricity from hydroelectric generation in cloudiest of locations in the Pacific Northwest.

UW professors Hugh Hillhouse and Alex Jen have been studying the factors that influence the cost of solar energy. The major factors that contribute to the cost of electricity from present day solar cells are the efficiency in converting sunlight to electricity, the cost of processing the materials and fabricating the devices, and the cost of assembling and installing solar cell systems.

Striving for high-efficiency and low-cost, Hillhouse and Jen have developed a method to fabricate a tandem, or "stacked," solar cell by printing inks that yield materials with high bandgap and low bandgap on top of each other. The two materials work in tandem to generate more voltage and power than can be created with either material by itself. In particular, working with the UW Center for Commercialization, Hillhouse has patented unique device architectures that may allow these solar cells to reach 30 percent efficiency. By comparison current-day low-cost polycrystalline silicon solar modules are around 15 percent efficient. In addition, Jen has patented new materials and interface chemistry that allow key layers in the tandem to be printed. Working together, the team hopes to be able to print a new generation of high-efficiency low-cost solar cells.

Their initial research, funded in part by the UW Clean Energy Institute, helped the team win $1.5 million of funding from the Next Generation Photovoltaics 3 Program, which is part of the U.S. Department of Energy SunShot Initiative.

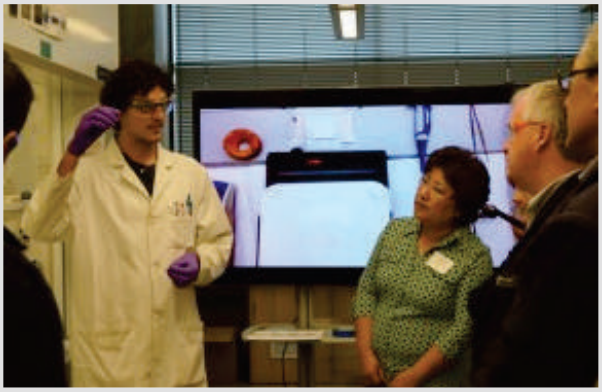
Building Teams and Seeding Research in Critical Areas

- Seeded 19 innovative research ideas, leading to two patent applications, numerous publications, and a $1.5 million Department of Energy SunShot grant for research on newly discovered perovskite photovoltaics
- Recruited four exceptional faculty to the UW: Vincent Holmberg (Assistant Professor of Chemical Engineering), Cody Schlenker (WRF Assistant Professor of Chemistry and Clean Energy), Venkat Subramanian (WRF Associate Professor of Chemical Engineering and Clean Energy; joint appointment with PNNL), and Baosen Zhang (Assistant Professor of Electrical Engineering)
- Four additional faculty hires planned in 2014-2015 for interdisciplinary research positions in battery materials, energy systems recruitment partnering, and advanced manufacturing recruitment (part of larger UW cluster hire)

Developing Future Leaders in Clean Energy

- Supported 53 Graduate Fellows via the Graduate Fellowship and Student Training & Exploration Grant Programs
- Established the Washington Research Foundation Innovation Fellows Program to help attract the next generation of innovation leaders to the UW with support for three postdoctoral fellows annually
- Created an Interdisciplinary Seminar Series to bring distinguished seminar speakers such as Mildred Dresselhaus (MIT), Cyrus Wadia (Lawrence Berkeley National Lab on assignment at the White House Office of Science and Technology Policy), and Harry Atwater (Caltech) to campus

September 2014: Washington State Legislators Visit CEI



State Representatives Cindy Ryu and Jeff Morris learn about cutting edge solar energy materials research at the UW

A group of more than 20 Washington state legislators and staff members received an update on CEI work on September 29. This visit allowed the elected officials, government staff members and industry partners to get a close look at the results of the state's investment as well as the institute's progress in research dedicated to next generation solar energy materials, storage devices and renewable energy integration into the smart grid.

During the tour they met new energy research faculty who recently joined the CEI, and experienced high-powered microscope and laser demonstrations using state-of-the-art equipment used by UW faculty and industry partners to study and develop new energy materials.

CEI Director Dan Schwartz kicked-off the visit with an overview of the institute's accomplishments during in the past year. The tour concluded with a poster and demonstration session that allowed graduate and undergraduate students to present their research on clean energy topics and discuss their educational experience with state legislators and staff.

Leadership & Key Supporters

Clean Energy Institute Leadership Team

Daniel T. Schwartz, Director; Boeing-Sutter Professor of Chemical Engineering
David S. Ginger, Associate Director; Alvin L. and Verla R. Kwiram Endowed Professor of Chemistry and WRF Distinguished Scholar
Alex K-Y. Jen, Chief Scientist for Technology Integration; Chair and Boeing-Johnson Chair Professor, Materials Science & Engineering

Clean Energy Institute Advisory Council

Jack Faris, Senior Counselor, APCO Worldwide (Chair)
Maggie Brown, Managing Director, APCO Worldwide
Dan Caldwell Project Director, McKinstry
Bob Drewel, Former Executive Director, Puget Sound Regional Council
Denis Hayes, President, Bullitt Foundation
Alvin Kwiram, Emeritus Professor of Chemistry and Former VP for Research, UW
Daniel Malarkey, VP for Business Development and Public Policy, 1Energy Systems
Susannah Malarkey, Executive Director, Tech Alliance
Bob Moore, Marketing Consultant
Eileen Quigley, Director of Strategic Innovations, Climate Solutions
Gary Shaver, President, Silicon Energy
Stephanie Solien, Member, Social Venture Partners Seattle
Gretchen Sorensen, Principal, The Sorensen Group
Tim Zenk, Vice President of Corporate Affairs, Sapphire Energy

Clean Energy Institute Member Faculty

* CEI Faculty Advisory Board Member

Stuart Adler, Associate Professor, Chemical Engineering
Guozhong Cao, Professor, Materials Science & Engineering
Brandi Cossairt, Assistant Professor, Chemistry
Scott Dunham, Professor, Electrical Engineering
Daniel R. Gamelin, Harry and Catherine Jaynne Boand Endowed Professor, Chemistry*
David S. Ginger, Professor and Kwiram Endowed Professor of Chemistry and WRF Distinguished Scholar*
Hugh W. Hillhouse, Rehnberg Chair Professor of Chemical Engineering *
Vincent Holmberg, Assistant Professor, Chemical Engineering
Alex K-Y. Jen, Boeing-Johnson Chair Professor, Materials Science & Engineering *
Samson A. Jenekhe, Boeing-Martin Professor of Chemical Engineering
Daniel Kirschen, Close Professor, Electrical Engineering *
Jiangyu Li, Professor, Mechanical Engineering *
Xiaosong Li, Associate Professor, Chemistry
Christine Luscombe, Associate Professor, Materials Science & Engineering *
Miguel Ortega-Vazquez, Assistant Professor, Electrical Engineering
Lilo D. Pozzo, Associate Professor, Chemical Engineering
John J. Rehr, Professor, Physics
Cody Schlenker, WRF Assistant Professor of Chemistry & Clean Energy
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Gerald T. Seidler, Professor, Physics
Venkat Subramanian, WRF Associate Professor of Chemical Engineering & Clean Energy
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