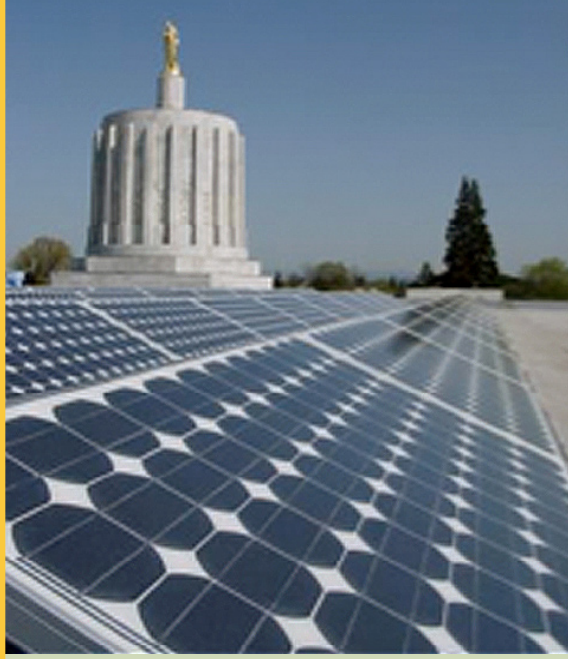


OREGON'S UNIVERSITIES KNOW SOLAR:

Investing in Solar Energy R&D, Partnering with Solar Companies, and Developing a Solar-Savvy Workforce

Workforce Development • Oregon Academic Research Facilities • Research Expertise

Oregon was the first state in the U.S. to install photovoltaics on its capitol building. Now, Oregon leads the nation in recruiting and supporting solar energy companies that have open access to our university network of cutting-edge solar research facilities and world-renowned faculty researchers.

In addition, Oregon's colleges and universities are educating new graduates who are highly trained in solar energy technologies and have hands-on experience in solar research labs. These men and women are ready to meet the growing workforce needs of Oregon's booming solar energy sector.

Known worldwide for our obsession with renewable energy, green technologies, and sustainable living, Oregon—and its research universities—have for years been at the forefront of renewable, green energy research, from solar and wind energy to biofuels and green roofs. In fact, the *Princeton Review* recently named the University of Oregon one of only 11 U.S. universities to its inaugural "Green Honor Roll," and its faculty members are world leaders in the "green chemistry" revolution.

Today, with guidance from the **Oregon Built Environment & Sustainable Technologies Center (Oregon BEST)**, Oregon is investing millions of dollars in the expansion of a state-wide network of research tools and faculty expertise aimed at fast-tracking solar technologies and serving solar energy businesses in Oregon. This unique network of laboratories, equipment, faculty researchers, and graduate students is here to partner with private companies and public agencies to ensure that solar energy succeeds—not only here in Oregon but around the world.

WORKFORCE DEVELOPMENT: A WIN-WIN EQUATION

Partnering with Oregon's Solar Industry to Educate Excellent Employees

The large existing workforce in Oregon's semiconductor industry makes Oregon an ideal location for solar PV manufacturing companies. Our universities and colleges already have specialized programs for graduate students as well as technicians who want to join the solar energy workforce, and our state-wide academic strengths in chemistry, physics, and engineering are nationally recognized.

Our research and learning institutions are currently partnering with solar companies and looking to expand collaborations to ensure that the academic curriculum matches the workforce needs of the solar industry.

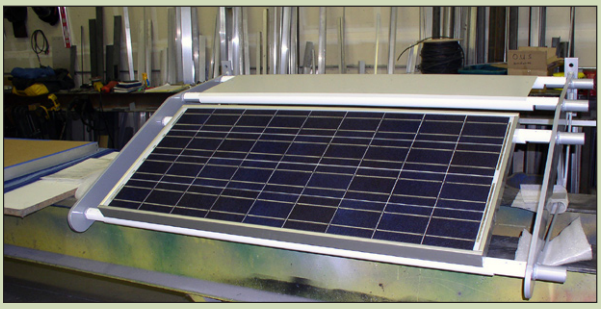
By building unique partnerships between Oregon's universities and the solar industry, companies here have access to a full-spectrum supply of workers who are custom-educated to meet precise labor needs across the solar energy

supply chain. Some of our educational programs aimed at the solar industry include the following:

- **Graduate Industrial Internship Program**
  Operated by the Materials Science Institute at the University of Oregon, the 10-year-old **Graduate Industrial Internship Program** offers individuals with backgrounds in chemistry, physics, or engineering a master's or PhD degree in chemistry or applied physics. The curriculum is constantly being refined and enhanced because it is built around the specific needs of local high-tech companies that provide valuable input to the program. The Semiconductor Device Processing Program, which has been placing graduates in Oregon's semiconductor industry for more than 10 years and is expanding to include a PV focus, begins with a summer of intensive course and lab work. Both master's and PhD candidates participate in paid, 9-month internships at regional companies while maintaining connections with faculty via meetings and seminars. The program places special emphasis on developing communication, leadership, problem solving, and teamwork skills so that graduates enter the solar industry equipped with the soft skills as well as with the technical expertise and experience that companies require. The Semiconductor Device Processing Program is one of four programs offered; the other three are: Optical Materials and Devices; Polymers and Coatings; and Organic Synthesis and Organometallics.

- **Renewable Energy Engineering Degree Program**
  Offered at both Oregon Institute of Technology (OIT) campuses in Klamath Falls and Portland, the **Renewable Energy Engineering Degree Program**—the first of its kind in North America—arms new graduates with a bachelor's degree in Renewable Energy Engineering. Students of the innovative program graduate prepared for immediate employment in the solar energy industry. OIT's main campus in Klamath Falls is the only geothermally heated university campus in America. OIT is also home to the Geo-Heat Center, a national resource for geothermal development, and the Oregon Renewable Energy Center (OREC), which conducts applied research on photovoltaic power systems, and other clean energy systems.

- **Portland Community College's New PV Technology Degree**
  One of the largest photovoltaic manufacturers in the U.S. is partnering with **Portland Community College's** (PCC) microelectronics program to develop graduates who specialize in solar cell manufacturing. As a result of the partnership, PCC, with eight locations in the greater Portland area, has developed a new PV technology associate's degree and is establishing a scholarship for the program. In addition to the new program, a short-term training certificate of completion in solar technology will also be offered.



- **Northwest Energy Education Institute**
  Located at Lane Community College (LCC) in Eugene, Oregon, the **Northwest Energy Education Institute** has been a national leader in renewable energy technician training for 30 years. Graduates of the Energy Management Program evaluate energy use of residential and commercial buildings and recommend solutions for reducing energy consumption via efficiency and alternative sources. Graduates of the Renewable Energy Technician Option are trained to recommend specific energy conservation systems and to install photovoltaic and solar domestic hot water systems. LCC offers the nation's only two-year Associate of Applied Science (AAS) degree in Energy Management and is one of only a few colleges offering an AAS for Renewable Energy Technicians.

OREGON'S ACADEMIC RESEARCH FACILITIES:

Sharing Facilities and Faculty with Oregon's Solar Industry to Advance Solar Power Worldwide

The people at Oregon's universities and colleges welcome the opportunity to collaborate with solar energy companies locating in Oregon, where our academic research teams are helping companies solve complex problems—onsite at industry facilities and in university labs.

Oregon has already invested heavily in its network of solar research test equipment and laboratory facilities located at universities and signature research centers throughout the state, and many of our solar energy research faculty working at these facilities are world-renowned experts in their fields. With input and direction from the **Oregon Built Environment & Sustainable Technologies Center (Oregon BEST)**, even greater investments in research equipment and facilities are planned for the near future.

Part of Oregon's unique academic commitment to support the solar industry is the formation of an industry-faculty committee that will make recommendations for future equipment purchases and lab expansions. In this way, Oregon's solar sector will play a critical role in helping define the laboratory equipment and research thrusts that industry most needs now, as well as in the future.

This intense emphasis on win-win collaborations between Oregon's academic institutions and the state's booming solar industry is unique in the nation, making Oregon the most progressive and proactive U.S. state when it comes to recruiting, supporting, and building long-term relationships with the solar energy industry.

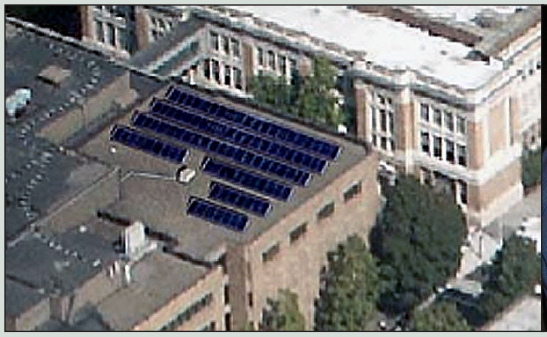
The following is a list of the major R&D facilities available to the solar industry for research and development. (Oregon's solar energy faculty members and their specific laboratory research are described in the "Research Expertise" section that follows this one.)

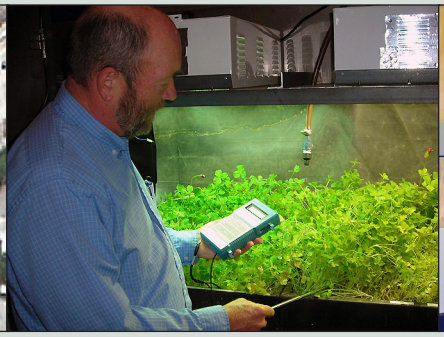
The new **Oregon Built Environment & Sustainable Technologies Center** is rapidly investing in R&D equipment that industry and academia can share to advance solar energy technologies and manufacturing processes. Recently, Oregon BEST funded acquisition of a suite of testing equipment needed to pursue development of novel composite semiconducting structures, acquisition of a solar simulator, a device that simulates the sun's illumination, and is helping fund the design of a microchannel-based solar receiver for biofuel processing and a scalable catalytic microchannel reactor for solar thermal fuels production. In the coming three years, Oregon BEST has plans to lead the investment of an additional $5 to $10 million in new university equipment and lab space to make Oregon the national epicenter of solar research.

The **Oregon Nanoscience and Microtechnologies Institute (ONAMI)** is a community of world-class industry, academic, and federal research institutions that is moving nanoscience and microtechnology innovations from basic research through to commercialization. ONAMI has more than $50 million in shared user facilities and equipment that is very relevant to solar energy research and development. All ONAMI facilities, like those being funded by Oregon BEST, are open to industry research partners, because we believe that by working together, we all benefit.

The **Center for Advanced Materials Characterization in Oregon (CAMCOR)**, is Oregon's high-tech extension service. Located at the University of Oregon, CAMCOR is a full-service, comprehensive materials characterization center available to research institutions and private industry. The CAMCOR facilities provide enabling infrastructure for research in chemistry, nanoscience, materials science, bioscience, and optics. CAMCOR houses capital-intensive equipment for microanalysis, surface analysis, electron microscopy, semiconductor device fabrication, as well as traditional chemical characterization. Staff members who run the facilities are expertly trained and highly experienced in sample preparation, data collection and data analysis. In addition, they periodically offer workshops to provide hands-on-training for users of the facility.

The **Oregon Renewable Energy Center** was established in 2001 at the Oregon Institute of Technology to integrate renewable energy technologies into energy systems





for practical use by businesses and consumers. The center enhances development and promotes renewable energy through energy systems engineering, applied research, technical assistance, information dissemination, academic degree programs, and industrial training and development.

The new **Portland State University Photovoltaic Test Facility** on the rooftop of Cramer Hall in downtown Portland, Oregon features nine different solar PV arrays from a range of manufacturers. PSU professor Carl Wamser and his research team, including University of Oregon professor Frank Vignola, an expert in solar data collection and archiving, test different PV systems, collecting and streaming data and images over the internet and via a web cam to faculty researchers and students, the solar industry, and the general public. Wamser is also working on a proposal that would explore using solar PV systems to shade plants on green roofs and using green roofs to help cool PV systems.

The **Lorry I. Lokey Laboratory** houses $30 million in nano-characterization and fabrication equipment at the University of Oregon. With more than 30,000 square feet (2800 m2), this state-of-the-art underground facility sets a new performance standard for vibration, electro-magnetic interference and temperature control. This collaborative space, which houses CAMCOR, brings together researchers from multiple disciplines in academia and industry.

For more than 30 years, the **Solar Radiation Monitoring Laboratory** at the University of Oregon has been in continuous operation, monitoring sites throughout the Pacific Northwest to provide high quality scientific data for solar energy resource evaluation and long-term climate studies.

Some of these facilities are described in greater detail in the following "Research Expertise" section.

OREGON'S SOLAR ENERGY RESEARCH EXPERTISE:

Helping Solar Energy Companies Solve Problems, Advance Research, Succeed

Built on existing, strong expertise in PV research and materials characterization, Oregon's academic research programs are focused on advancing current and future solar energy technologies, and on helping solar energy companies located here solve problems.

Oregon's researchers, who collaborate across institutional and public-private boundaries and partner with national labs, are frequently asked to consult for major players in the solar industry, and their network of shared facilities is an asset to solar companies locating in Oregon.

Federally funded programs in solar energy research are currently underway at all of Oregon's major research universities, where academic scientists are using increased state investment in solar research to leverage additional research funding.

To keep up with the exponential growth in the solar industry—and the ensuing demand for skilled workers—Oregon plans to hire 10-15 new faculty members across the university system in the next year or two whose solar energy expertise will make Oregon's solar research capability second to none in the U.S.

The following list summarizes the research labs and associated faculty researchers currently involved in PV research at Oregon's major academic institutions. This list describes two representative research laboratories at each university, along with more brief summaries of other related activities and faculty members.

UNIVERSITY OF OREGON

J. David Cohen *(Physics)*

Researchers in Cohen's laboratory have been studying the properties of thin film semiconductors with direct application to photovoltaic technologies for more than 25 years, receiving more than $4M in outside funding for such work over this period. Materials currently being studied include amorphous silicon, the amorphous silicon-germanium alloys, nanocrystalline silicon, plus copper indium diselenide (CIS) and its related alloys. Federal funding during 2007 for such PV related thin-film semiconductor research exceeded $300,000, with the major portion coming from two Solar America

Initiative contracts from the Department of Energy. Cohen's laboratory has collaborated closely with many industrial R&D and National Laboratory scientists including United Solar, BP Solar, the Institute of Energy Conversion (Delaware), ITN Energy Systems, Nanosolar, Shell Solar International, Energy Photovoltaics (EPV), and the National Renewable Energy Laboratory.

Mark Lonergan *(Chemistry)*

Researchers in Lonergan's laboratory have been studying organic semiconductors for more than a decade. Currently, these include a novel class of organic materials that more closely mimics the properties of inorganic semiconductors, such as silicon, while preserving the advantages of organic materials in terms of low-cast fabrication. Group members work on the development and synthesis of new organic semiconducting materials, the fundamental understanding of their electrical properties, as well as the exploration of novel device architectures. The Lonergan group's work in organic semiconductors has attracted more than $1.5 million in external funding, including a recent $450,000 grant from the Department of Energy–Basic Energy Sciences for the fundamental study of a new class of organic photovoltaics. The group collaborates strongly with Voxtel, an Oregon company, and interacts with researchers at the Portland State University, the University of California, Santa Barbara, the University of Victoria, and the National Renewable Energy Laboratory.

Other faculty members at the University of Oregon who are interested in the development of advanced photovoltaic materials and who have recently submitted proposals for funding in this area include **Steve Kevan** *(Physics)*, who has expertise in the study of fundamental processes at semiconducting interfaces, and **Geri Richmond** *(Chemistry)*, who has expertise in ultra-fast laser studies of carrier dynamics in semiconductors. **Dave Tyler** *(Chemistry)* has been studying the synthetic chemistry and photoresponse of semiconductor nanomaterials with an emphasis on new ways for efficiently harnessing solar energy. **Dave Johnson** *(Chemistry)* has extensive expertise in thin film technologies covering a wide range of materials, and his group is developing a powerful approach to synthesizing new materials including those for photovoltaic applications. **Frank Vignola** *(Physics)* is the Director of the University of Oregon's Solar Radiation Monitoring Laboratory. For 25 years he has been a leader in efforts to increase the utilization of solar energy in Oregon and has recently been focusing on methods to incorporate solar energy design features into buildings.

OREGON STATE UNIVERSITY

Douglas A. Keszler *(Chemistry)* and John F. Wager *(Electrical Engineering)*

For three years, researchers in this group have been pursuing development of novel materials for pin double-heterojunction thin-film solar cells with funding from the National Renewable Energy Laboratory. This work is a spin-off of ongoing and prior research activities involving topics such as transparent electronics (they developed the world's first transparent transistor), printed electronics, thin-film electroluminescence, and atomic resolution storage. The operative research paradigm is 'rapid materials development', since it involves the selection, design, assessment, and optimization of materials in powder, dense pellet, or thin film form, which can be accomplished quickly and economically, in contrast to most electronic/optical device-related development that requires the use of expensive single crystals. These efforts have recently led us to the development of unique bipolar wide band-gap semiconductors and new methods for printing light capturing optics.

Hewlett-Packard and Oregon State University recently announced the licensing of transparent electronics technology to Xtreme Energetics of Livermore, California, to enable development of non-mechanical solar tracking systems and up to 50 percent output improvement over existing stationary panels.

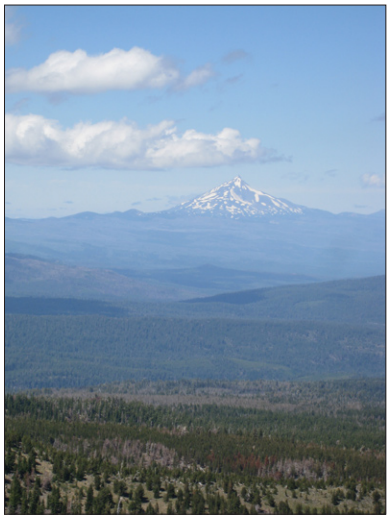
Other faculty members at Oregon State University who are interested in the development of advanced photovoltaic materials and who have recently submitted proposals for funding in this area include **Janet Tate** *(Physics)* with expertise in the study of fundamental transport and optical processes in wide band-gap semiconductors and **Chih-Hung Chang** *(Chemical Engineering)* with expertise in the deposition and study of thin-film absorber materials.



PORTLAND STATE UNIVERSITY

Carl Wamser *(Chemistry)*

The Wamser group does basic research in novel solar energy materials, an approach that is sometimes called artificial photosynthesis because some of the materials and strategies are similar to those used by nature. Nanostructured, electronically conductive polymers of porphyrins serve as the basis for a new type of photovoltaic cell. The work involves collaborations with professor Rolf Könenkamp in Physics (see below) and Dr. Glen Fryxell at the Pacific Northwest National Lab. Funding has come from the U.S. Department of Energy, the Research Corporation, and the Murdock Foundation. Wamser is also the principal investigator on a DOE-funded project that has established a photovoltaic test facility on the roof of Cramer Hall on the PSU campus in downtown Portland, Oregon. This facility includes nine different 1 kW solar arrays, with data streamed via the internet, and via a unique collaboration with the Oregon Museum of Science and Industry (OMSI). The intent is to provide useful and engaging data about solar energy for multiple constituencies: students, educators, researchers, contractors, manufacturers, and the general public.



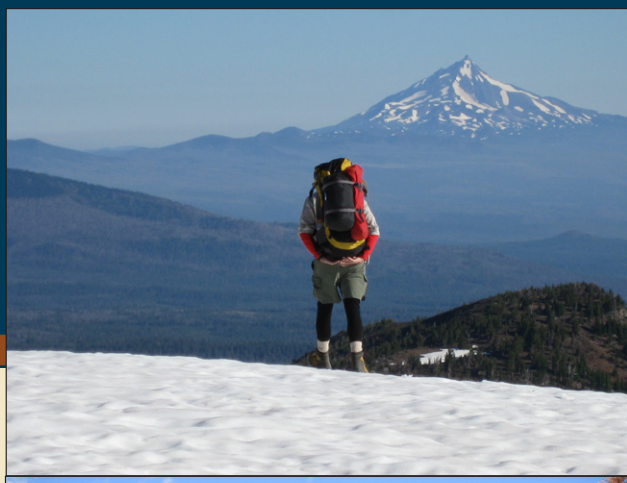
Rolf Könenkamp *(Physics)*

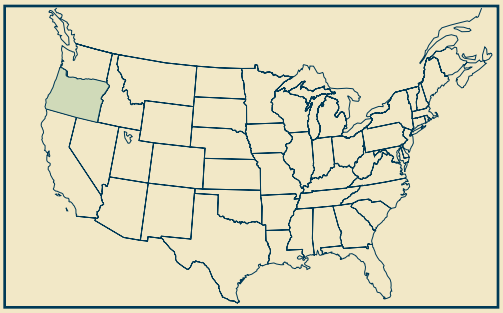
Researchers in this lab have been studying novel semiconductor device concepts for transistors, LEDs, and solar cells. The utilization of nanostructures in these devices has enabled the group to design flexible, as well as ultra-thin devices, and permitted them to introduce novel low-cost processes for device fabrication. The group is also engaged in developing an improved electron optical tool with superior sensitivity for the characterization of small structures. Könenkamp's experience in photovoltaics covers two decades of work on amorphous Si and compound semiconductor solar cells. Currently, his group is working on a nanostructured hybrid solar cell combining organic and nanoscale inorganic materials. In the last four years external funding of $2 million USD has been acquired from institutional and industrial sources.

Other faculty members beginning to work in this area at Portland State University include **Raj Solanki** *(Physics)* who has extensive experience across the semiconductor field with focus on novel processes and devices. His current research includes novel photovoltaic devices based on nanowire structures and conductive organic materials. Solanki is currently a member of SPIE's Nano Photonics & Cell Technologies Program Committee for Photovoltaics.

OREGON:

The Home of Solar Energy R&D in the U.S.





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