CCIA Colorado Cleantech Industry Association

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University of Colorado Boulder

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Research Rock Stars

Colorado universities are teeming with genius talent whose work carries great commercial potential for the cleantech industry **BY CHRIS SHAPARD**

What are research rockstars? MIT and Stanford know what they are. But does Colorado?

What and who are Colorado's research rock stars?

They are the men and women at the University of Colorado, Colorado State University and Colorado School of Mines who make game-changing discoveries in their labs AND are engaged in seeing those discoveries translated into products to be used for the greater good. They are researchers and entrepreneurs. They are Rock stars! We're so excited to share their stories here.

Why do we care?

The researchers commercializing university discoveries bring value to Colorado in several ways. The intellectual property (IP) produced by them within our research institutions is an asset of the state. If it is determined that the IP has market potential, then there are opportunities to move it into the marketplace by licensing it to a company.

When licenses are agreed upon and royalties received, the resulting revenues return to our state institutions. At a time when state support of higher education is at its lowest point, this provides a means to backfill the missing state funding.

Our research rock stars are also instrumental in creating jobs in Colorado. When a company licenses university technology and sets up shop in Colorado, it begins to create direct jobs within the company — hiring scientists, business development and other executive talent. Additionally, startup companies require the services of accountants, attorneys, prototyping companies and other contractors that help grow employment in those sectors, as well. So, you see, these Research Rock stars really do influence job growth in Colorado.

Colorado Clean Technology Discovery Evaluation Grant Program

It takes a lot of hard work and money to successfully commercialize research discoveries. That's why the Colorado Cleantech Industry Association has worked diligently to fund the "Clean Technology Discover Evaluation Grant" program.

With the passage of SB 11-47 by the 2011 General Assembly, $2 million per year of grant funding will available for 10 years to conduct market assessments of technologies within the universities, to support companies commercializing university technologies and to initiatives that bridge the research–industry gap.

Funding at this early R&D stage has been proven to create jobs and companies, and is used as leverage to attract the professionally managed investment capital that our companies need to grow.

CCIA's Celebrate Cleantech Research!

As the only statewide cleantech organization working with CU, CSU, CSM and the National Renewable Energy Laboratory to help bridge the divide between research and commercialization, the Colorado Cleantech Industry Association (CCIA) believes it is important to recognize the gems we have in Colorado.

Kudos and congratulations go to Katie Johnson at Colorado School of Mines, Amy Prieto, Bryan Willson, W. S. Sampath and Chuck Henry at Colorado State University and Bob Erickson, Gregor Henze and Al Weimer at the University of Colorado. We appreciate their scientific brilliance and entrepreneurial vision that enables their technology to move into the global marketplace.

Chris Shapard is executive director of the Colorado Cleantech Industry Association.

Research Rock Stars

The heroes of CU, CSU and the Colorado School of Mines are creating technology that is moving into the marketplace

STORAGE STAR

CSU chemistry professor Amy Prieto aims for all-electric vehicles

Amy Prieto is in hot pursuit of the automotive industry's holy grail — a battery powerful and cheap enough to make all-electric cars the go-to clean energy vehicle.

The young CSU chemistry professor parlayed her research in nanotechnology into Prieto Battery, a 2009 startup that hopes to produce batteries far more powerful and longer lasting, and much cheaper, than traditional ones. The technology also has potential applications that range from the military to health care to smart phones.

"If our battery works to its potential, it could be the ideal battery for an electric car," Prieto said. "We've had some cool breakthroughs recently, so I'm pretty excited."

Once a battery is "turned on," much of its efficiency is derived from how many live wires come in contact with each other. Using nanotechnology, the wires used in Prieto batteries cover a surface area that is 10,000 times greater than a traditional battery. A thousand such nanowires could fit in the width of a human hair.

Prieto joined CSU in 2005 as an assistant professor. She did her post-doctoral research at Harvard and received her doctoral degree from the University of California-Berkeley. She is now part of the univer-

sity's Clean Energy Supercluster, known as Cenergy, which was formed to commercialize the research done at CSU. In 2009, when Prieto cofounded Prieto Battery, it was Cenergy's first startup.

Tim Reeser, Cenergy's chief operating officer, also lent a hand as unpaid CEO of Prieto Battery for a year.

"What stood out with Prieto Battery was the potential for transformational change," Reeser said. "If you look at the other battery startups around, almost all of them are trying to achieve incremental change. They either have a battery that is 10 percent better, or they have one that is much better but costs a fortune."

Prieto Battery also represented the first investment made by CSU Fund 1, a private equity fund set up to help the university bring its faculty's research to the marketplace.

"We were looking for game-changers, and this is one," said Mark Wdowik, executive director of the fund, which invested $250,000. That money, along with funding from Bohemian Asset Management in Fort Collins, has taken Prieto's battery research closer to the marketplace.

"We've grown from doing research out of my lab to a lab with three full-time Ph.D. scientists and one full-time technician," Prieto said. "We also added a chief finance officer and a vice president for marketing and strategic alliances."

Prieto Battery is hardly alone in its quest. Several dozen U.S. companies, from startups to General Motors, are racing to build better batteries.

"Almost all the others are trying to optimize one piece of their battery," Prieto said. "We are building a whole new kind of architecture. Now that we have discovered some new materials, we can build full batteries and see how long they last and how fast we can charge them."

Prieto's business plan calls for shipping a prototype battery to third-party testing labs in six to eight months.

"All our in-house testing looks really good," she said. "Once it's thoroughly tested, we can move pretty aggressively to commercialize it. That's why we have a marketing person – to begin establishing relationships with customers."

At CSU, Prieto has adjoining labs with her husband, Matt Shores, also an assistant chemistry professor. They share an equipment room – and also share a daughter, Alena, who will turn 3 this summer.

– Rob Reuteman

WATER STAR

CSU's Chuck Henry using integrated circuits to study drinking water contaminants

Chuck Henry has loved the art of experimentation since he was a small boy visiting his father's chemistry lab at College of the Ozarks in Branson, Mo.

He says he always was destined for a life in science even though he didn't necessarily enjoy the side of chemistry that keeps most who practice it cooped up for hours inside in stale laboratories.

Henry, a Colorado State University professor, has developed a way around that with patent-pending technology that allows him to work in the field and still conduct experiments once

confined to labs with the same accuracy while finding answers much quicker than before.

Henry developed Lab on a Chip using integrated circuit technology from the manufacturing sector to help him identify the elements in samples from the air we breathe to drinking water to blood. It also dramatically cut the cost from more traditional analysis to as little as $5 per test.

"We're trying to make chemistry the size of a credit card," Henry said.

Henry's research breakthrough ultimately led to the formation of Advanced MicroLabs LLC, a Fort Collins-based company using the technology for further research in a wide variety of applications. Advanced MicroLabs has five full-time employees and five part-time employees

"I've always kind of kept my eye open," Henry said. "If we do things in my academic lab that can help people and make a useful product, it's something I've always been interested in doing. A lot of the things we do in the academic lab is research, and it will never make it any further than my lab. But I would say we are always kind of looking for those opportunities."

Henry, a father to five sons ranging in age from 4 to 16, spent a month in California earlier this year looking at small air particles in the atmosphere in trying to understand how people are affecting climate and the air we breathe.

He will return to California later this summer to work on identifying drinking water contaminants using lab on a chip technology.

The company also is doing work on cancer technologies trying to use its techniques and product to provide doctors and clinicians answers about diagnosis in a matter of minutes at a cost estimated to be one-tenth of what traditional tests and laboratories require.

"It's just something I have always enjoyed," Henry said. "I enjoy the creative side of science. This is a way I get to do different things and try different things that aren't limited by what I would say are traditional instrumentation and traditional approaches."

– Kyle Ringo

CLEAN TRANSPORTATION STAR

CSU's Bryan Willson helps take cleantech products to market

It's difficult for Bryan Willson to explain what he does.

Willson is a professor of mechanical engineering at Colorado State University. He's the founding director of CSU's Clean Energy Supercluster, a group of 150 faculty members working with clean energy companies to move new products to market. He is also founder and director of CSU's Engines and Energy Conversion Laboratory (EECL), which conducts research on transportation, indoor air quality, distributed energy and other areas.

"It sounds somewhat scattered," Willson says. "What ties it together is we use science to develop solutions to large scale energy problems, and then use entrepreneurial/market approaches to disseminate the results globally on a large scale."

He says some researchers develop a technological solution, write about it in an academic journal, then move on to another project. Instead, the Supercluster and EECL focus on market-driven solutions.

One example is cookstoves. EECL designed clean, efficient cookstoves for people in Asia, Africa and Latin America. "Half the world's population cooks on wood, dung, crop residues, and straw, and the smoke kills 2 million people a year," Willson says. "We develop stoves that burn those fuels much more completely, reduce emissions by 80 percent, and reduce fuel use by half." In 2004, Willson cofounded Envirofit International, which manufactures the stoves.

In 2006, Willson cofounded Solix Biofuels, which makes large-scale algae growth systems. According to the Solix website, biofuels made from algae can help reduce the need for finite, nonrenewable petroleum used in transportation, and thus help solve energy dependence.

Willson received his Ph.D. from the University of Texas at Austin in 1988, the same year he joined the CSU faculty. Although mechanical engineering is usually associated with cars, the department opted to work on underserved areas such as large industrial engines. "It wasn't particularly sexy like cars were, but if we developed something that improves performance, it's easier to move those solutions into production," he says. "That's when your work has impact, when it goes into production."

He founded EECL in 1992 in an abandoned power plant owned by the city of Fort Collins. The EECL expanded its scope to fuels, the smart grid, and other areas. The lab partners with local companies Spirae Inc. to make smart grid solutions, and Woodward Inc. and Dresser-Rand Enginuity to manufacture control systems for large industrial engines. The cookstoves are made overseas, including China, where Willson and CSU are working to build a research institute.

"There is no way to avoid engagement with China in the energy field," Willson says. "You risk being irrelevant if you don't work with China."

– Nora Caley

WIND STAR

Kathryn Johnson of the Colorado School of Mines spends her time testing turbines

Kathryn Johnson says one of the biggest challenges she faces in her wind energy research is the lack of test sites. "Most modern utilities won't let you run tests on their million-dollar turbines," she says. "It's difficult to get test time on turbines."

The Clare Boothe Luce Assistant Professor at Colorado School of Mines Division of Engineering says she makes up for it by doing simulation work, and by working on one of the large turbines at the nearby National Renewable Energy Laboratory in Golden. She worked at NREL as a summer intern, then worked there four years, and still does research in collaboration with the lab.

Johnson researches control systems on wind turbines. The analogy, she says, is cruise control or traction control in a car. On a wind turbine, the control system makes the turbine operate as efficiently as possible, and also works to reduce the dynamic loads on the turbine structure. "When a wind gust comes in and hits the turbine, that puts force that bends the tower or bends the blade, so the idea with control systems is, can we do anything to reduce the bending?"

The system can pitch the blades, which means to adjust the angle to change their rotation speed. Another process relies on sophisticated generator and power electronics. "We can ask the generator to draw a certain load torque or load power from the turbine," she says. "It gets very complex."

She says everything she does has the ultimate goal of reducing the cost of wind energy. That includes increasing efficiency of the turbine, figuring out how to get more energy from a turbine, and reducing loads, which will increase the turbine lifetime.

Johnson earned her bachelor of science degree in electrical engineering from Clarkson University in Potsdam, N.Y., in 2000. Two years later she earned a master of science in electrical engineering from the University of Colorado Boulder. In 2004 she earned her Ph.D. at CU Boulder. The title of her 107-page dissertation was, "Adaptive Torque Control of Variable Speed Wind Turbines."

Control systems is not one of the divisive topics in wind, so Johnson doesn't often deal with controversies such as where to build wind farms. The question she does often field is, why does it seem like the turbines at NREL, off the very windy Highway 93, are almost never turning?

"They are intended as research turbines, not power production turbines," she says. "Many times they are setting up experiments, so if you're going up and down the tower with equipment, you want the turbines shut off." *– Nora Caley*

BIO-DERIVED STAR

Al Weimer, University of Colorado

The end of the 1985 film "Back to the Future" features Dr. Emmett Brown returning to present day in his time machine to pick up Marty McFly so he can return to the future and show him a problem concerning McFly's children.

Before they can make the trip, Brown opens a trash can in the driveway and begins placing garbage in a processor where it is turned into fuel for the time machine made from a DeLorean automobile.

In the movie, the year in which fuel from trash is possible is 2015. University of Colorado chemical engineering professor Al Weimer and his team beat that prediction by a few years by successfully turning yard clippings into green gas.

"This is the most direct route to replacing significant amounts of imported oil," said Weimer, who is working with Sundrop Fuels to commercialize the technology. "It will happen, and it will be large scale. If gasoline prices keep going up, we may be closer than anyone thinks."

No word on whether Weimer plans to tackle the concept of flying cars or time travel.

Weimer didn't set out to make gas from grass. He and his team of researchers, comprised mostly of students and funded by a Department of Energy grant, were developing a new way to split water and create hydrogen using sunlight and mirrors to superheat a cauldron of water and zinc. They were successful and only turned their attention to focusing sunlight on the grass clippings and creating green gas later.

"I like the challenge of making the better mousetrap," Weimer said. "I like being first in an area and working at the interface of technologies – like thermochemical biomass conversion. A lot of discovery happens at the interface, but it's very difficult to obtain funding there because funding supports specific silos.

"All my career, people have told me I could not do certain things. If I know it's possible and I understand the scientific fundamentals, I consider that a huge opportunity."

Weimer, now in his mid 50s, worked in private industry for 16 years before starting a career in academia and research in 1996. Several products of his research have been commercialized, and he admits he is hoping to make the big idea happen at some point "so that I never have to write another research proposal."

Weimer is co-founder of ALD NanoSolutions Inc., which uses atomic layer deposition and thin-film technology to develop coatings for a variety of hardware products and batteries.

Weimer says his true passion is working with his students.

"Being an academic teacher, researcher is the best job in the world," he said. "I have a direct impact on people — students — and it can impact their lifetime. I work incredibly hard, but enjoy it. I left industry because the fun went away."

– Kyle Ringo

SOLAR STAR

W.S. Sampath founded Abound Solar based on CSU research

It's an exclusive club Dr. W.S. Sampath belongs to.

Not many people can claim to have revolutionized a field of study and product development on a scale with the potential to affect the entire world.

Sampath's life's work has been focused on improving solar technology to the point where implementing it as a primary energy source is equal to or even more cost effective than traditional fossil fuels.

His manufacturing process for solar panels using thin-film technology and cadmium telluride marked a major step forward that could impact how the world generates and uses energy for generations to come.

Sampath, a 55-year-old professor of mechanical engineering at Colorado State University, founded Abound Solar (formerly AVA Solar) in 2007 to commercialize the technology. The company has since grown to employ more than 300 people and has raised more than $250 million in private financing.

"I was thinking that we would just do the research and put it into a publication and some company would take it from there," Sampath said. "At that time I did not realize there is a lot more that needs to be done other than what you do in a university lab."

Sampath grew up the son of a scientist in Chemnai, India. He came to the United States in 1980 and earned his masters degree from Arizona State University in 1985. He was hired as a professor at CSU shortly after that and almost immediately began the research that eventually led to his thin-film breakthrough.

He said the federal government opened Palo Verde Nuclear power plant at a cost of about $6 billion in the mid-1980s. When he came to CSU at about the same time, he began doing work for the Anheuser-Busch brewery which opened at a cost of $30 million. Both plants served as an inspiration for Sampath to generate more efficient, safe and cost-effective means of energy production.

The current solar technology Sampath developed allows for between 10 percent and 11 percent of sunlight to be converted to electricity. He is working now to expand that capacity to 20, 30 or even 40 percent one day.

Sampath used to hope he was impacting the lives of the students who enrolled in his courses each year and aided him in his research. His dreams have expanded exponentially in recent years.

"Making solar advances is No. 1 beyond anything else because it means so much," Sampath said. "You're not affecting just 10 or 20 people. You're talking about billions of people on the planet. I'm more focused on making the advances in the research sense." *– Kyle Ringo*

EFFICIENCY STAR

CU's Gregor Henze focuses on the electrical demand of commercial buildings

To ensure that electricity is available when we want it, we currently require a complex array of generating technologies. We put on costly peaking power plants to meet peak demands, such as on hot summer afternoons. But demand always plummets at night, preventing more extensive use of larger and more efficient baseload generating plants.

In response to this challenge, the University of Colorado and Clean Urban Energy Inc. (CUE) of Chicago, through a collaborative research agreement initiated in September 2008, have developed and deployed solutions that focus on the electrical demand of commercial buildings. Such buildings typically reduce demand only sporadically during times of stress on the electrical grid. This new approach, however, creates elasticity in the electric demand; an elasticity that is both continuous and scalable.

The core software engine, created at CU Boulder by architectural engineering professor Gregor Henze, Ph.D., and doctoral student Charles Corbin, implements model predictive control (MPC) strategies as part of a software-as-a-service (SaaS) platform. This platform shapes the electric demand of a building's heating, ventilating and air-conditioning system by harnessing the building's thermal mass embodied in concrete, furniture and books. In this way, the MPC platform turns buildings into thermal batteries capable of storage on a multi-megawatt scale.

The MPC modeling approach uses information about both building structure and operations to provide site-specific performance predictions. The core software engine then applies multi-attribute optimization techniques to help determine the most economical operation of the building for each day. Factored into this prediction are predicted local weather, carbon emissions at the source, fan and chiller efficiencies, and real-time electric market prices.

Ultimately, the technology uses the thermal mass of these buildings as large-scale thermal energy storage for urban smart grids. This storage capacity introduces demand flexibility into electric grids while improving the reliability of the grid itself. The ability to shape the electric demand of buildings allows for significantly expanded penetration of intermittent renewable energy and cogeneration systems with greatly reduced carbon emissions.

Professor Henze, his research group, and CUE are now investigating how portfolios of commercial buildings could be assembled to provide benefits in collaboration that exceed the benefits of individual buildings. Much like grid resources acting in concert to achieve economy and reliability, buildings within portfolios contain complementary features and capabilities that they plan to coordinate for synergistic effect. The technology harnesses the inherent physical and operating flexibility of commercial buildings to create value for, and provide services to, the electric grid at low cost.

– Allen Best

SMART GRID STAR

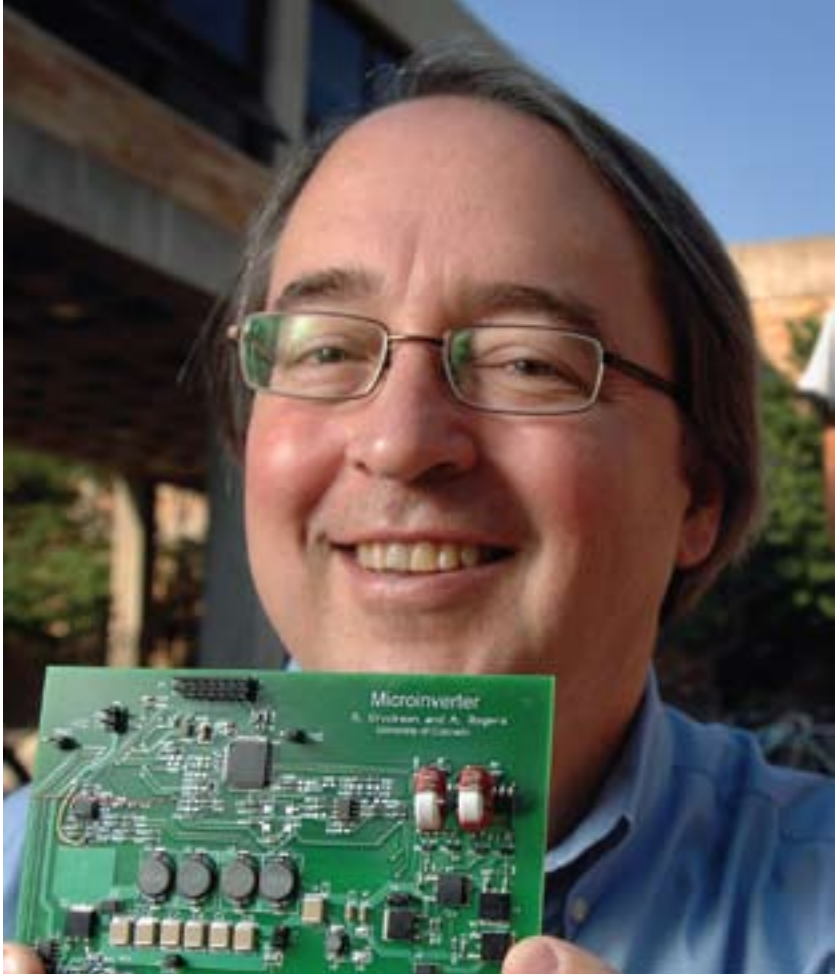
Robert Erickson, University of Colorado

If you look at the houses in a typical neighborhood, few have roofs facing directly south. Even when they do, dormers in the house or nearby trees may block the sun, limiting where solar panels can be placed and reducing the effectiveness of those that are.

The architecture of the electrical circuitry also limits a panel's effectiveness. It's a bit like a string of Christmas lights, where one burnt-out or blinking bulb causes all other lights to go dark. Something similar happens in a PV cell. A patch of shade over a very small portion of the panel can cause all of the cells to perform less effectively. All of the cells must be lined up at attention or the whole unit gets sub-par performance.

Robert Erickson, a professor of electrical engineering at the University of Colorado-Boulder since 1982, believes he has answers to curb this slacking of solar panels. Backed by what he identifies only as a Fortune 50 company, Erickson has established a Lafayette-based company called Phobos. The name is an acronym for photovoltaic balance-of-system; the latter phrase strikes at the heart of his breakthrough work.

"We aren't necessarily going to point our panels north, but we can point them to the east or west, southeast or south-



west, and they can still be effective," Erickson says.

Erickson's specialty, power electronics, is to build electronic circuits that control and change electrical power. Plugging an electrical device into a wall socket employs power electronics. So does an electric car, taking direct current out of the battery and converting it to alternating current to turn the wheels.

"For most of my career, you would do a fun project with solar panels at the school, but when it came time to make a living, you would do other things," Erickson said.

Erickson wants to produce building-integrated photovoltaic systems that will be low in cost, high in power production, and easy to install. If he can connect on all three counts, he and his backers believe it will make economic sense to use Phobos on every new roof.

That would be a huge transformation. Solar, despite its relative profusion, has made only small inroads in Colorado. But an efficient, cost-effective rooftop solar collector on every house – to go with a car in the garage and a chicken in the pot. Well, that's a micro-grid for the new American dream.

– Allen Best