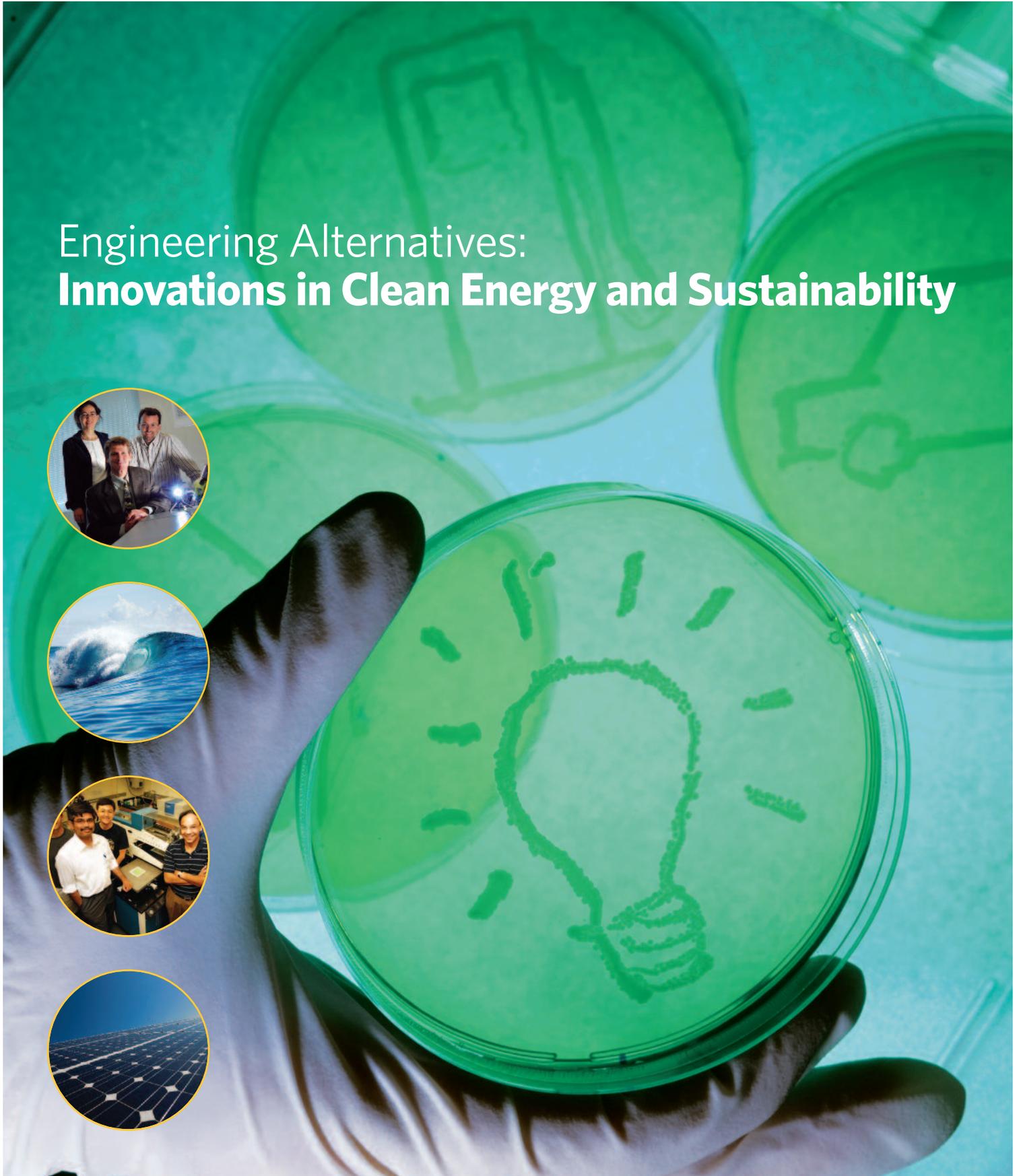


Engineering Alternatives: **Innovations in Clean Energy and Sustainability**



Engineering a Cleaner, Greener World

Global climate change, fossil fuel depletion and the quest for energy independence have intensified the demand for high-impact innovation in clean energy and sustainability. Recognizing the critical importance of cleantech breakthroughs to the nation and the world, Boston University's College of Engineering has put forward a unique and diverse portfolio of leading-edge research and educational programs.

Their primary objective is to investigate and develop novel technologies and processes that exploit clean energy sources while promoting environmental, economic and social well-being. To that end, College of Engineering faculty and students—drawing on core competencies in advanced genomics, electrochemistry, nanotechnology, structural acoustics, solid-state materials and devices, thermodynamics, systems engineering and other disciplines—are advancing several promising solutions.

Their efforts could lead to devices that generate electric power from bacteria, ocean waves or sunlight; economical fuel cells and hydrogen production systems; more energy-efficient building, lighting and transportation systems; and a smart grid that considerably reduces fossil fuel consumption.

To achieve their goals, College of Engineering researchers and educators routinely collaborate with colleagues throughout Boston University, as well as with other academic, government and industry partners. Facilitated by the university-wide Clean Energy and Environmental Sustainability Initiative (CEESI), these collaborations integrate expertise in technology, policy, climate science, market economics and systems integration.

Combining a strong commitment to academic and research excellence with an entrepreneurial spirit, the College of Engineering is at the forefront of the nation's efforts to ensure a more sustainable and prosperous future.



"Through collaborations with Professor Michael Caramanis (ME) and others within the BU community, I have been able to publish and present at important conferences in the energy sustainability and engineering fields. In addition, we have been leading an initiative to create a living laboratory for a Smart Neighborhood in the Back Bay of Boston. The goal is to spread awareness on energy efficiency issues, as well as to begin to bridge the gap between the consumer and utility side of the meter."

Justin Foster
PhD Candidate, Systems Engineering



Academic Programs

Guided by accomplished faculty members, Boston University College of Engineering undergraduate and graduate students may pursue a wide range of course offerings and research projects that explore clean energy technologies and their potential impact on society.

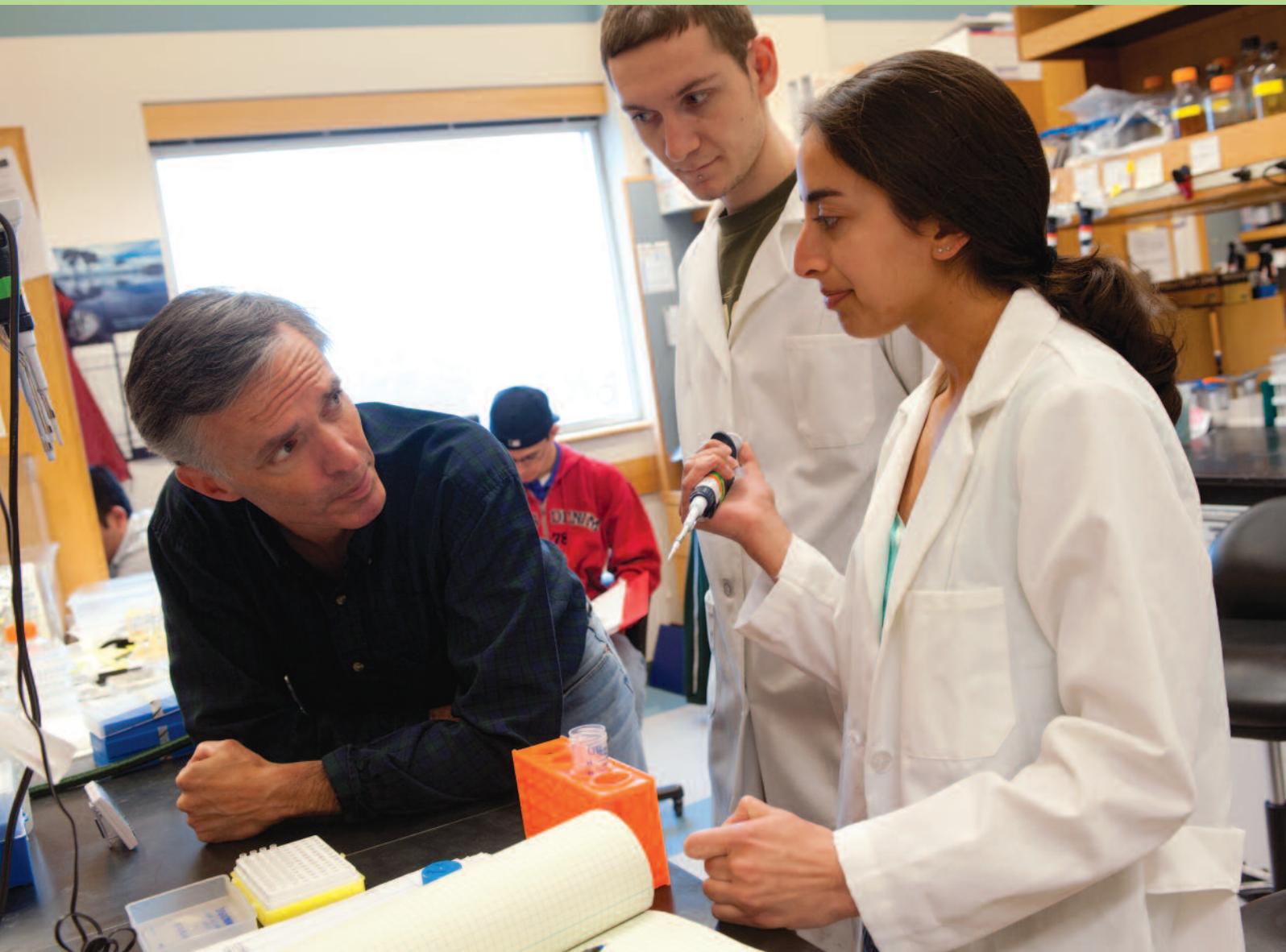
Undergraduate Concentration in Energy Technologies and Environmental Engineering (ETEE)

bu.edu/eng/ugrad/concentrations/etee

The ETEE concentration enables College of Engineering undergraduates to better position themselves for careers in one of today's signature engineering fields. Affording greater access to the faculty's innovative clean energy and sustainability research, the concentration enables students to acquire a basic understanding of the environmental impacts of various energy generation and utilization technologies, and to design environmentally sustainable engineering systems.

Courses and Research Opportunities

Undergraduate and graduate students are attending courses and conducting research in several disciplines that relate to clean energy and sustainability. A partial list includes advanced coatings for energy efficiency; bioenergy; carbon dioxide sequestration; fuel cells and batteries; green manufacturing; networked systems for the Smart Grid; novel materials for hydrogen storage; ocean wave energy; solar and wind energy systems; solid state lighting; sustainable power systems planning, operations and markets; and thermofluid sciences.



Research

Boston University's College of Engineering is advancing promising solutions to challenging problems in clean energy and sustainability. Collaborating with experts in academia, government and industry, our faculty and students are spearheading innovations in technology, commercialization and public policy to balance tomorrow's energy demands with ongoing environmental, economic and social needs. Here are 11 areas in which their efforts are making a difference.



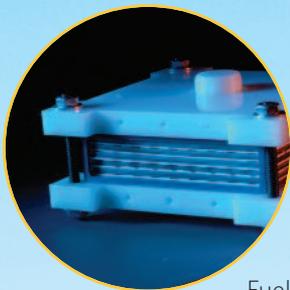
Bioenergy

Recovering energy from waste and reducing waste disposal are necessary for creating a sustainable modern society. Division of Materials Science and Engineering faculty and students have developed a technique to convert hydrocarbon-rich municipal, agricultural and industrial solid waste to hydrogen, which can then be used within a fuel cell to produce electricity, or as a transportation fuel. Similarly, biological organisms represent a promising new clean energy harvesting resource, and computational systems biologists in the Biomedical Engineering Department are manipulating proteins and genes in microbes' metabolic networks to produce hydrogen gas and "bacterial fuel cells" that convert sugar sources into electricity.



Green Manufacturing

Conventional primary metal production methods emit carbon dioxide or chlorine, but College of Engineering researchers have devised an electrolysis method to produce pure metals from their oxides with zero carbon emissions—and at a fraction of the cost. Their energy-efficient, one-step method promises to significantly reduce greenhouse gas emissions throughout the industrial sector and enhance U.S. energy security and economic growth. Partnering with industry, the researchers are developing their method to produce pure magnesium for the manufacture of lightweight, more fuel-efficient motor vehicles, and to extract pure silicon from sand (silicon dioxide) for use in solar cells.



Fuel Cells, Fuel Processing and CO2 Sequestration

Fuel cells promise to reduce pollution and provide stationary, distributed or mobile power production from renewable and nonrenewable sources, but manufacturing them can be expensive. College of Engineering researchers have devised a novel process to manufacture solid oxide fuel cells that delivers equivalent performance at far less cost than conventional approaches. They have also come up with a new solid oxide membrane method to process fossil fuel that yields pure hydrogen and sequesters carbon dioxide. The fundamental understanding gained from such electrochemical systems can be applied to batteries and other clean energy technologies.



Nanophotonics-Enhanced Photovoltaics

In collaboration with ARPA-E and technology startups, the College of Engineering is supporting several efforts to design functional nanomaterials that not only boost solar energy collection efficiency but also can be produced cheaply and at a sufficiently large scale to effect real change in the nation's energy mix. All exploit photonics technologies developed at the Center for Nanoscience and Nanobiotechnology (CNN). Examples include graphene-based, transparent window coatings that absorb energy from a broader portion of the solar radiation spectrum, and metallic nanostructure arrays and rare-earth atoms that, when coupled to solar cells, improve solar-electric conversion rates.



Capturing Ocean Wave Energy

If harnessed efficiently, ocean wave power could provide more than 10 percent of the world's energy and reduce its carbon footprint by two billion metric tons. Drawing on a century of combined research experience in wave mechanics, vibrations, energy conversion and electromechanical systems, mechanical and electrical engineering researchers aim to produce cost-competitive systems for delivering ocean wave energy to coastal regions. Unlike typical solutions that involve expensive, custom-designed, massive sea vessels, the researchers envision deploying scalable networks of low-cost, desk-sized buoys made of time-tested marine components. Devices inside each buoy will convert the mechanical energy of waves to electric power.



A Smarter Grid

In collaboration with the College of Arts and Sciences, the School of Management and industry partners, College of Engineering researchers are advancing a more intelligent electric power grid that could considerably reduce the nation's electricity costs and carbon footprint. Drawing on core strengths in information and communications technology and systems engineering, they're designing point-of-consumption monitors and controllers and optimization algorithms to enable the grid to minimize power consumption and costs. Research goals range from coupling intermittent, renewable energy sources with rechargeable, plug-in, hybrid electric vehicles, to testing neighborhood-scale, smart micro-grids aimed at improving the efficiency and resiliency of local energy infrastructures.



More Efficient Solar Cells

Commercially available solar cells cannot absorb a significant portion of the solar spectrum, limiting their maximum efficiency (how much absorbed light gets converted to electricity). But College of Engineering researchers are working to develop low-cost, next-generation solar cells aimed at producing at least a 10 to 20 percent efficiency improvement over what's now on the market. Their approach involves the strategic layering of indium gallium nitride quantum dots (nanoscale semiconductor particles) of varying sizes. Other College-based innovations in this area include an electrostatic method to clean sun-blocking dust from solar cells, and carbon nanotubes for enhanced solar energy applications.



Improved White-Light LEDs

Providing the same light for less than half the energy required by a compact fluorescent bulb, a high-quality white-light LED would reduce U.S. energy costs by up to \$20 billion and carbon dioxide emissions by 150 million tons annually. But today's white-light LEDs are inadequate for use in general lighting applications. To produce white light that you could read by, blue, green and red LEDs must be combined—and making green LEDs is very inefficient and costly. College of Engineering researchers are working to resolve this "green gap" by developing semiconductor particles called quantum dots that exhibit unique properties.



Greener Buildings

Since buildings account for 40 percent of U.S. energy consumption, they are prime targets for efficiency improvements. In partnership with industry, researchers at the College of Engineering, College of Arts and Sciences and School of Management are collaborating to improve the energy efficiency of existing and new buildings. Their technical focus is on developing improved HVAC design and control strategies, which are significantly more energy efficient and highly economical. They are also developing business mechanisms to accelerate investment in green building technologies, and designing new contracts and business models to finance investment in sustainable buildings.



Low-Power, Adaptive Lighting

Lighting accounts for about one-sixth of all energy consumption, but replacing conventional bulbs with light emitting diodes, or LEDs, would reduce that fraction considerably. Even more energy and cost savings could be achieved with "Smart Light" LEDs, computer-controllable bulbs that College of Engineering researchers are developing that provide illumination and enable optical wireless communication and networking among electronic devices within a defined space. Accessed individually across a digital network, Smart Lights can be programmed to provide illumination only as needed, and exploited by a smart grid to reduce electricity demand within a room, building or city during peak periods.



More Energy-Efficient Gas Turbines

Increasing the operating temperature of gas turbines used for aerospace and energy generation applications will reduce fuel utilization through improved efficiency and cleaner combustion byproducts. To enable a significant operating temperature increase, College of Engineering researchers are developing novel environmental barrier coatings, currently under a BU patent, that allow the introduction of ceramic components into gas turbines. They are also developing thermal barrier coatings with engineered crack microstructures that will allow turbine components in the hot-stage to tolerate higher combustion temperatures without a reduction in lifetime. More recently, they're combining both types of coatings into a single advanced coating system.



"Cleantech is unique in that it requires a convergence of ideas from business, technology and policy, and BU has strengths in all three areas. Thanks in part to connections I made in the College of Engineering's Green Manufacturing course and at the BU Energy Club, I landed a full-time position at one of the fastest growing cleantech companies."

Michael Galbo
M.S. in Materials Science and Engineering, 2009; commercial building energy analyst at EnerNOC

Collaborating Across Boundaries

Clean energy and sustainability research and education at Boston University's College of Engineering are interdisciplinary enterprises enriched not only by colleagues throughout the BU campus, but also by other academic, government and industry partners.

CAMPUS-WIDE INITIATIVES

- Clean Energy and Environmental Sustainability Initiative (CEESI) bu.edu/energy
- Boston University Energy Club people.bu.edu/buenergy
- GLACIER: Global Change Initiative: Education & Research bu.edu/energy/research/interdisciplinary_project/glacier-project
- Presidential Lectures on Clean Energy and Environmental Sustainability bu.edu/energy/events/pres-lectures
- Sustainability@BU bu.edu/sustainability/what-were-doing/energy

RESEARCH CENTERS AND PROGRAMS

- Center for Information and Systems Engineering (CISE) bu.edu/systems
- Center for Nanoscience and Nanobiotechnology (CNN) nanoscience.bu.edu
- NSF Smart Lighting Engineering Research Center at BU bu.edu/smartlighting
- Photonics Center bu.edu/photonics

INDUSTRY AND GOVERNMENT PARTNERSHIPS

- Clean Energy Partners bu.edu/energy/outreach/partners
- Green Manufacturing people.bu.edu/upal/research.htm
- NSF Smart Lighting Engineering Research Center bu.edu/smartlighting
- Nanophotonics-Enhanced Photovoltaics
- Smart Grid Research Consortium bu.edu/energy/outreach/consortium/consortium
- Smart Neighborhood bu.edu/energy/research/smart-grid
- Sustainable Buildings bu.edu/energy/research/projects/green-building-technologies



"A special topics course on 'Building Energy Use and Energy Efficiency' launched my career as an energy engineer. Today I am working with building owners and facility managers to identify and evaluate actionable energy efficiency and renewable energy savings opportunities throughout the country."

Elijah Ercolino

M.S. in Mechanical Engineering, 2010; Energy Engineer at Nexamp, Inc.



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“In collaboration with Research Professor Malay Mazumder (ECE), I have been researching self-cleaning solar panels that can help improve photovoltaic efficiency. Through this research I have been able to work toward advancing clean energy production.”

Jeremy Stark
PhD Candidate, Electrical and Computer Engineering