ENERGY EXPLORERS

Northwestern Engineering researchers and innovators are pioneering new technologies, materials, processes, and products to power a sustainable future.

CREATING A FUTURE POWERED BY SUSTAINABLE ENERGY IS ONE OF SOCIETY'S BIGGEST CHALLENGES—a challenge intensified by the increasingly evident threat of climate change.

While global energy demand keeps rising—global energy demand will rise 47 percent by 2050, according to the US Energy Information Administration—much of our energy still comes from finite resources. Many of the processes that power our lives remain energy intensive.

Such complex problems inspire Northwestern Engineering faculty and students, who are approaching energy sustainability across the entire lifecycle: how we source the energy we need, how we store it, how we distribute it through the power grid, and how we use energy to produce goods and power our daily lives.

top to bottom
column 1
Sossina Haile
Michael Bedzyk
Vinayak Dravid
column 2
James Rondinelli
Chris Wolverton
Lin Chen

NEW RESEARCH CENTER TO DEVELOP HYDROGEN TECHNOLOGIES

"OUR CENTER FOCUSES ON THE SCIENCE OF HYDROGEN IN MATERIALS AS A FOUNDATIONAL STEP TOWARD CREATING A SUSTAINABLE ENERGY SOLUTION."

SOSSINA HAILE
Walter P. Murphy Professor of Materials Science and Engineering

To help combat climate change—and funded with more than $10 million from the US Department of Energy—Sossina Haile, Walter P. Murphy Professor of Materials Science and Engineering, is heading up Northwestern's new Hydrogen in Energy and Information Sciences (HEISs) Energy Frontier Research Center.

"It is now almost trite to acknowledge that climate change is an existential crisis—but the urgency of the situation can't be repeated enough," says Haile, a fuel cell pioneer whose work centers on sustainability and social good on a global scale.

Through the center, researchers will develop hydrogen-based energy technologies, working to provide a scientific foundation for practical developments in carbon-neutral energy (including nitrogen and carbon dioxide reduction) and materials for brain-inspired computing.

Hydrogen has tremendous societal importance in energy technologies and growing importance in energy-efficient computing. In both arenas, the relevant devices are limited by hydrogen kinetics, whether electrochemical reaction at an interface or diffusion through the bulk, and whether the material is an electrolyte, a semiconductor, or a metal.

HEISs will establish the governing mechanisms and physical descriptors of the transport as well as the interfacial incorporation mechanisms needed to achieve precision-guided discovery and design across these classes of materials. The research team will focus on use-inspired, ambient-to-intermediate temperatures to advance the center's goals. This includes controlling electrochemical transformations critical for carbon-neutral energy and for modulating electron transport in computing materials.

Five other Northwestern faculty members—Michael Bedzyk, Vinayak Dravid, James Rondinelli, and Chris Wolverton from engineering, and Lin Chen from chemistry—and six researchers from an additional five universities, are co-principal investigators.

"Our center focuses on the science of hydrogen in materials as a foundational step toward creating a sustainable energy solution," Haile says. "Beyond that, we will exploit the unique influence of hydrogen on material properties to create new ways of computing for information sciences. We have put together a spectacular team of experimentalists and computationalists, and I am absolutely thrilled to lead this effort."

ENHANCING MATERIALS DEVELOPMENT FOR RENEWABLE ELECTRICITY STORAGE

Jeffrey Richards

> "There are exciting opportunities that arise from this research, including technologies that are used for impact sensing in soft robots and as replacements for optical encoders."
>
> **JEFFREY RICHARDS**
> Assistant Professor of Chemical and Biological Engineering

To harness the full power of renewable energy sources like wind and solar, researchers are looking for better ways to store these energies. Recent work by a Northwestern team could impact the design of next-generation grid-scale electrochemical storage.

Jeffrey Richards, assistant professor of chemical and biological engineering, and his collaborators identified a particular contribution to charge transport in flow battery technologies—energy storage technologies that pump electrically active fluids to store renewable electricity for later use. The key enabling feature of these fluids is their ability to maintain a connected and dynamic network while flowing that enhances electron transport beyond the predictions of current theories.

Richards and his team developed a new framework to design these fluids by combining experimental evidence and computer simulations, which quantified the origin of electrical transport in concentrated suspensions of semiconducting and metallic particles. This research could set the stage for advancing the design of emerging electrical energy storage systems.

OPTIMIZING THE POWER GRID

Andreas Wächter Ermin Wei

> "OUR WORK PROVES THAT WE CAN SOLVE THESE IMPORTANT DILEMMAS AND REPRESENTS A FIRST STEP TOWARD IMPROVING THE OPERATION OF THE POWER GRID USING MORE EXACT MODELS."
>
> **ANDREAS WÄCHTER** Professor of Industrial Engineering and Management Sciences

As renewable energy sources become more prevalent, Northwestern professors are working to ensure current power systems operate more efficiently.

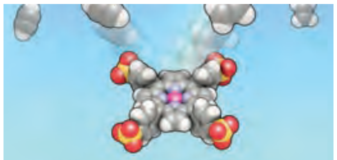
Participating in the US Department of Energy's Grid Optimization (GO) Competition, professors Andreas Wächter and Ermin Wei and their team developed new algorithms that increase the speed and efficiency of routing power across the grid.

The team's approach acts as a counter to the current simplified formulations, which ensure power systems work, yet fall short of the optimal, precise approaches needed to foster a stronger, more resilient grid. The team received $400,000 in prize money from the competition to further develop their approach.

Wächter, professor of industrial engineering and management sciences, says the GO competition empowered him to pursue his burgeoning interest in optimizing power flow—and he's now committed to finding more novel solutions to improve power grid operations.

"We need more accurate, robust solutions as renewable penetration and complexity increase," Wächter says. "Our work proves that we can solve these important dilemmas and represents a first step toward improving the operation of the power grid using more exact models."

REDUCING PLASTIC'S ENERGY FOOTPRINT



Emily Weiss

Samuel I. Stupp

"OUR STRATEGY IS A FIRST, MAJOR STEP TOWARD PRODUCING THIS IMPORTANT COMMODITY CHEMICAL WITH THE LOWEST ENERGY FOOTPRINT POSSIBLE."

EMILY WEISS Professor of Chemistry

Inspired by nature, Northwestern Engineering professors are finding new ways to create important industrial products that require much less energy.

In a first for the field, a Northwestern team has used light and water to convert acetylene into ethylene, a widely used, highly valuable chemical and a key ingredient in plastics.

Traditionally, chemists have created ethylene through steam cracking, an industrial method that employs hot steam to break down ethane into smaller molecules, which are then distilled into ethylene. Achieving the high temperatures and pressures required for a successful chemical reaction requires an incredible amount of energy.

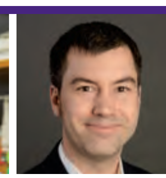
A collaboration between Northwestern faculty in the Center for Bio-Inspired Energy Science has discovered a photosynthesis-like process that is much less expensive and energy intensive. To convert acetylene into ethylene, Emily Weiss, professor of chemistry, and Samuel I. Stupp, Board of Trustees Professor of Materials Science and Engineering, Chemistry, Medicine, and Biomedical Engineering, replaced the process's traditional catalyst, palladium, with cobalt, a less expensive, more abundant alternative.

The researchers also used room-temperature and ambient pressure. In place of heat, they used visible light. And while the traditional process relies on protons from hydrogen, which is produced from fossil fuels and generates vast amounts of carbon dioxide, the team replaced hydrogen with plain water as a source for protons.

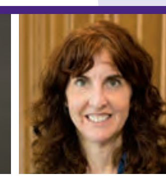
"Our strategy is a first, major step toward producing this important commodity chemical with the lowest energy footprint possible," says Weiss, who also has a courtesy appointment as a professor of materials science and engineering.

ENGINEERING BACTERIA TO CREATE FUELS

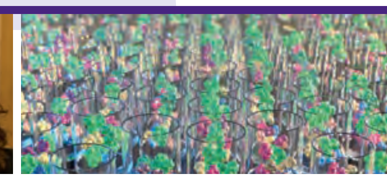
Michael Jewett



Keith Tyo



Linda Broadbelt



For years, synthetic biologists have worked to reengineer bacteria into tiny factories that produce renewable fuels and chemicals. In doing so, they hope to reduce both prices and energy use. Yet designing, building, and optimizing biosynthetic pathways in cells to produce these fuels remains complex, risky, and time consuming.

Professors Michael Jewett, Keith Tyo, and Linda Broadbelt are working with clean energy startup LanzaTech to find biosynthetic pathways within these organisms to optimize production of biofuels.

Jewett and collaborators from LanzaTech and the University of South Florida have optimized and implemented a pathway for the specific production of butanol, an alcohol biofuel, as well as butanoic acid, hexanol, and hexanoic acid across three biotechnological platforms.

"Our work forms a new blueprint for the generation and optimization of biochemical pathways for metabolic engineering and synthetic biology," says Jewett, Walter P. Murphy Professor of Chemical and Biological Engineering. "This will facilitate design-build-test cycles of biosynthetic pathways by decreasing the number of the strains to be engineered and the time required to achieve desired objectives."

Tyo, associate professor of chemical and biological engineering, is using computational design algorithms with Broadbelt, Sarah Rebecca Roland Professor of Chemical and Biological Engineering, to rapidly assess thousands of potential biosynthetic pathway designs that could optimize clostridia—bacteria that metabolize carbon—to produce butanol. To convert the carbon monoxide into butanol, enzymes spur chemical reactions. The Tyo lab simulates what the enzymes are doing in cell-free reactions to find the most efficient ways to make butanol, analyzing multiple choices to find the best options.

"Our work forms a new blueprint for the generation and optimization of biochemical pathways for metabolic engineering and synthetic biology."

MICHAEL JEWETT
Walter P. Murphy Professor of Chemical and Biological Engineering

DESIGNING LOW-CARBON BUILDINGS POWERED BY RENEWABLE ENERGY

"TREEHOUSE IS A BEACON OF THE POSSIBILITIES OF GREEN INFRASTRUCTURE, COMBINING MATERIAL AND OPERATIONAL SUSTAINABILITY WITH COMMUNITY ENHANCEMENT AND SOCIAL EQUITY."

ROBERT SZYMCZYK Civil Engineering Major

Strategies to combat climate change through lower energy usage also could tackle other issues, like affordable housing.

An interdisciplinary Northwestern Engineering student team designed a multifamily building that addresses Chicago's lack of diverse housing options and the built environment's contribution to CO_2 emissions. A 2022 Design Challenge Division Winner in the US Department of Energy Solar Decathlon, their design earned third-place honors in the competition's Multifamily Building Division.

The team's 10-floor development, called TreeHouse, includes eight floors of affordable housing units and two floors of dedicated commercial space designed to provide valuable resources such as a grocery store, daycare center, doctor's office, library, tutoring center, gym, and local retailers to residents of all income levels.

TreeHouse's holistic approach to sustainability features passive design strategies to optimize natural ventilation, daylight, and energy loads during Chicago's harsh winter and summer climates. The design leverages geothermal and solar energy, high-efficiency HVAC and graywater systems, natural and recycled materials, super-insulated and continuous envelopes, and prefabrication to reduce both the operational and embodied carbon of the building.

"TreeHouse is a beacon of the possibilities of green infrastructure, combining material and operational sustainability with community enhancement and social equity," says Robert Szymczyk, a civil engineering major and the team's project manager and design leader.