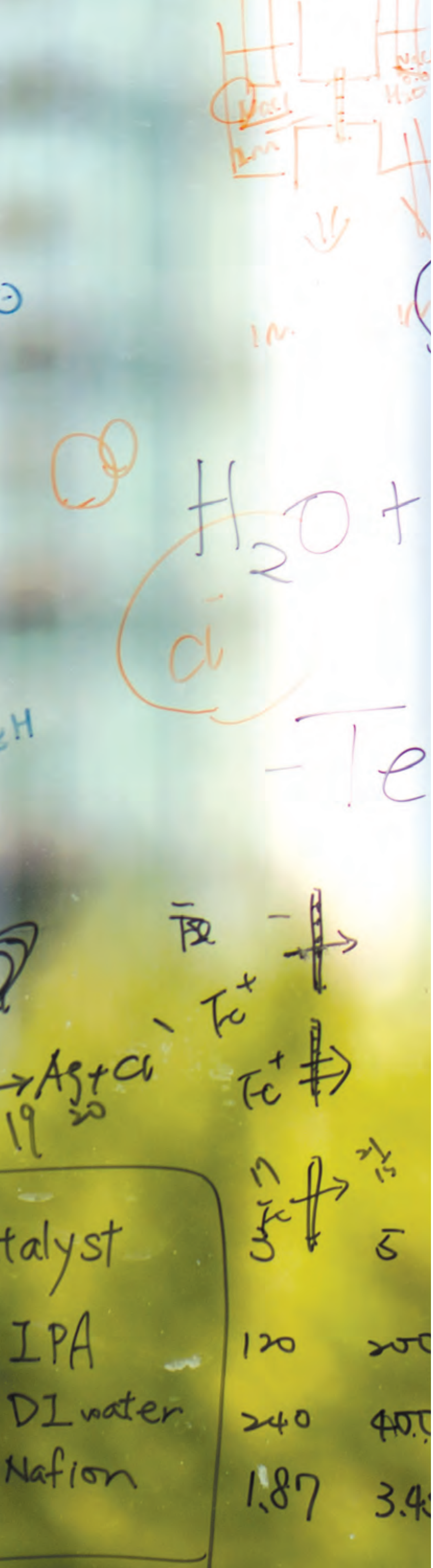
MITEI UROP

UNDERGRADUATE RESEARCH OPPORTUNITIES PROGRAM 2017

MITei
MIT Energy Initiative



About MITEI

The MIT Energy Initiative (MITEI) plays an important catalytic role in accelerating responses to many challenges facing our global energy system. We support energy research teams across MIT and forge collaborations with governments and industry to analyze challenges and develop cutting-edge solutions that advance technologies vital to addressing climate change and achieving a low-carbon energy future. MITEI also leads Institute energy education efforts and delivers comprehensive analysis to policymakers. Our accomplishments are facilitated by the investments of member companies, government grants and other funding, and individual donors.

Our education programs for undergraduate and graduate students provide hands-on experience that prepares tomorrow's energy researchers, engineers, analysts, and policymakers for exciting careers. These programs include the undergraduate Energy Studies Minor, MITEI's Undergraduate Research Opportunities Program, and the graduate Society of Energy Fellows.

ABOUT THE MITEI UNDERGRADUATE RESEARCH OPPORTUNITIES PROGRAM

Supporting undergraduate research is an important component of MITEI's commitment to training tomorrow's energy innovators to provide a growing global population with affordable, sustainable energy access and tackle climate change. MITEI encourages and supports student participation in energy research through our Undergraduate Research Opportunities Program (UROP).

MITEI UROP students are innovative problem solvers who become integral members of the labs in which they work. A UROP provides the chance to work closely with faculty, graduate students, postdocs, and research scientists.

Since the program's inception in 2008, MITEI and our member companies and donors have supported nearly 400 UROP students, including 18 students sponsored in 2017 (see pages 13-14 for a list of sponsors). In fall 2017, MITEI extended funding to include both spring and fall semesters, as well as the Independent Activities Period (IAP), which occurs between semesters.

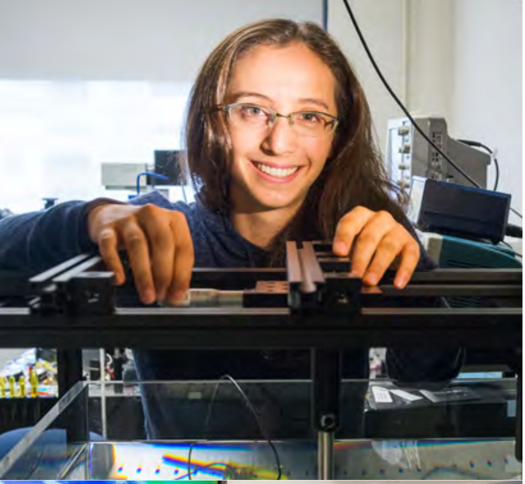
MITEI's support extends beyond the financial. Students gain practical insight by connecting with their sponsoring companies or donors. During the summer, weekly programming includes sessions on networking, creating and presenting research posters, and library research skills, as well as social activities. MITEI UROPs are welcomed into the undergraduate energy community, which includes access to the Energy Commons and informal support from other students and MITEI staff. Additionally, for the first time, MITEI summer UROPs were given the opportunity to present posters about their research at MITEI's Annual Research Conference in December 2017.

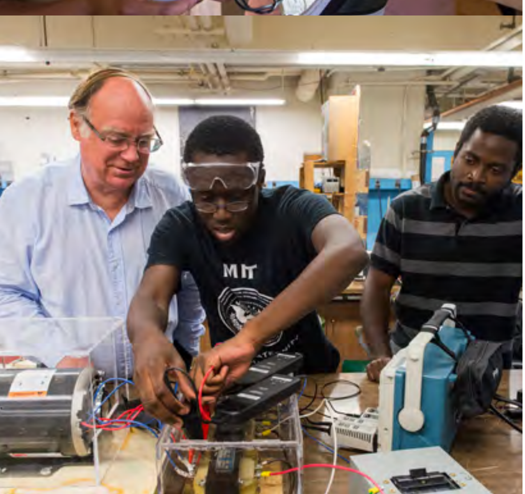
APPLYING

Students can choose to pursue a UROP for pay, academic credit, or on a volunteer basis. MITEI funding covers up to 150 hours of work during the semester and IAP and up to 360 hours of work during the summer.

Students interested in applying for a MITEI UROP can find instructions at energy.mit.edu/urop.

Questions can be directed to Rachel Shulman, MITEI Undergraduate Academic Coordinator, at rshulman@mit.edu or (617) 324-7236.



Meet the 2017 MITEI UROP students

"MIT students want to make the world a better place using their knowledge of science and engineering. It is rewarding mentoring these incredibly smart young scientists as they employ their skill sets and knowledge to help solve environmental problems and develop alternative energy strategies. The only thing better than making a discovery yourself is watching a student make his or her first discovery."

— Catherine Drennan
HHMI Professor and Investigator,
Departments of Biology and Chemistry,
MIT

Alexander Alabugin, '20

Chemistry

Advisor: Yogesh Surendranath, Paul M Cook Career Development Assistant Professor, Chemistry
Direct Supervisor: Bing Yan, Graduate Student, Chemistry

Sponsor: Alfred Thomas Guertin '60

Utilizing the proton and electron conductivity of WO_3 to facilitate selective electrocatalysis of the hydrogen oxidation reaction

I worked on a proposal to replace expensive membranes in polymer electrolyte fuel cells with a solid composite: catalytic platinum (Pt) deposited on a thin-film inorganic proton conductor, WO_{3-x}. An anode built in this way represents a possible bridge from gas to solution electrochemistry; pure hydrogen gas splits on the Pt, then protons spill off and hop through WO_{3-x} to end the solution circuit. The anode I helped prepare demonstrated high selectivity for hydrogen oxidation, even in an oxygen-rich environment, unlike free Pt, which indiscriminately catalyzes both. Such anode selectivity is considered an open problem. I dug deep into the literature on thin films, screening a range of proton-conducting materials and their physical/chemical methods of preparation, along with running experiments that probed the catalytic performance of the system. The project gave me a new appreciation for how work in basic materials chemistry can lift constraints on energy technologies and unleash new potential.

Ebrahim Al Johani, '19

Physics and Electrical Engineering and Computer Science

Advisor: Rajeev Ram, Associate Director and Professor, Electrical Engineering and Computer Science
Direct Supervisor: Amir Atabaki, Research Scientist, Research Laboratory of Electronics

Sponsor: Alfred Thomas Guertin '60

Near-infrared to blue light converter for implantable optogenetic applications

The aim of this project is to implement a design for a compact, implantable chip that could absorb infrared photons and convert them into blue light. Optogenetic research heavily relies on blue light and generally studies the interaction of neurons with light. My job was to study light energy harvesters and to design a circuit that could do the conversion necessary for this application—the hardest part was making it as small as possible to minimize foreign-body responses. I built a prototype and simulated how efficiently the device is when it's implanted beneath tissue. I learned a lot about how optics and light interact with biological tissue. Neuroscience is now a much more interesting field to me than when I began the project and I feel like I grew as a practicing scientist because of my deep involvement with a new, foreign, subject.

Michelle Bai, ’20

Economics

Advisor: Tonio Buonassisi, Associate Professor, Mechanical Engineering
Direct Supervisor: Ian Marius Peters, Research Scientist, Mechanical Engineering

Sponsor: Shell International

Data analytics and visualization for Summit Farms’ solar test bed

I worked with the MIT solar test bed team to visualize the data received from Summit Farms to involve the MIT campus with this new installation. Summit Farms is a large-scale, 60 megawatt solar farm in Currituck County, North Carolina that MIT sponsored through a power purchase agreement with Boston Medical Center and Post Office Square Redevelopment Corporation. Covering 650 acres and utilizing 255,000 panels, this farm is a unique source of solar energy data that makes available large quantities of data regarding not only power output, but also wind speed, module temperature, and plane of array, among others. My project involved parsing and visualizing the data in an understandable and aesthetically pleasing way to raise campus awareness of this new MIT resource. I used R to analyze trends in the data and D3.js and HTML/CSS to develop the user-friendly interface.

Songela Chen, ’19

Chemistry

Advisor: Catherine Drennan, Professor, Biology
Direct Supervisor: Lindsey Backman, Graduate Student, Chemistry

Sponsor: ExxonMobil

Structural enzymology of glycyl radical enzymes prominent in sulfur-reducing bacteria

Many bacterial species possess the natural ability to convert harmful pollutants in the environment into less toxic or non-toxic chemicals. Recently, it has become evident that a family of enzymes, called the glycyl radical enzymes, plays an important role in the basic biochemical pathways found in these bacteria. My project this summer aimed to find the structure of a new member of this family, isethionate lyase, via X-ray crystallography in order to gain insight into its mechanism of action. The process involved testing a variety of conditions to identify one that produced protein crystals, then optimizing the condition for high-quality X-ray diffraction, and solving the structure once I obtained a dataset. By the end of the summer, I successfully solved an initial structure of the enzyme and gained invaluable experience in wet-lab biochemistry. I was fortunate to work in a supportive and welcoming environment. Thank you MITEI for giving me this opportunity!

Alex Choi, '20

Materials Science and Engineering
Advisor: Jeffrey Grossman, Morton and Claire Goulder and Family Professor in Environmental Systems, and Professor, Materials Science and Engineering
Direct Supervisor: Grace Han, Postdoctoral Associate, Research Laboratory of Electronics

Sponsor: Shell International

Solar thermal fuels

Solar thermal fuels provide a new method of capturing renewable energy from the sun. They absorb heat energy or light energy from the sun and store it in chemical form through a physical change in the solar thermal fuel's molecular structure. When some form of trigger, such as ultraviolet or infrared light, is applied to the material, it releases its stored energy in the form of heat. Afterwards, the solar thermal fuel returns to its base state, ready to be charged again, with minimal loss of fuel over many charging cycles.

I learned how to use standard chemistry equipment and carry out many organic synthesis and chemical purification methods. I used the nuclear magnetic resonance and differential scanning calorimetry machines to generate data, interpreted it, and used it to write lab reports. I gained an understanding of how to do research in a materials science context and learned what life is like in research and development.

Caralyn Cutlip, '18

Mechanical Engineering
Advisor: Leon Glicksman, Professor, Architecture and Mechanical Engineering
Direct Supervisor: Jonathan Kongoletos, Graduate Student, Architecture

Sponsor: Lisa Doh Himawan '88

Thermally autonomous low-cost housing in India

Gujarat, India regularly has temperatures exceeding 40 degrees Celsius, and a huge portion of its population lives in slums with little or no shelter. These two facts combine to make heat a dangerous aspect of life there. During summer 2017, I worked on a team to design and build three thermal test chambers—essentially mini houses. Using these chambers, we tested the efficacy of different passive cooling techniques. We also improved a simulation of the experimental setup and compared the experimental data to the simulation prediction. Using this code, we hope to analyze many other passive cooling techniques, and use our results to design low-cost housing to replace the slums in Gujarat. Through this project, I gained valuable experience working on a team and many different skills relevant to my goals as a mechanical engineer interested in architecture. I'm continuing to work on this project during my senior year.

Tahina Felisca, '19

Mechanical Engineering

Advisor: Tonio Buonassisi, Associate Professor, Mechanical Engineering
Direct Supervisor: Mallory Jensen, Graduate Student, Mechanical Engineering

Sponsor: John C. Hardwick '92

Minimizing trapping in lifetime measurements

Multicrystalline silicon is an efficient and cost effective material, but its efficiency is dependent on the recombination lifetime of the cell's material which is the time required for charge carriers to recombine with electron holes. The MIT Photovoltaic Lab is studying these lifetimes to understand the cause of light- and temperature-induced degradation of solar cells. However, these measurements are affected by impurities in solar cells that create energy levels in band gaps which cause artificially high values for the lifetime measurements. Directing light on the carriers can lessen the effect of these traps. This project's goal is to create a custom bias light for the lifetime measurement instrument tool that can be used to lessen the effect of trapping on lifetime measurements.

Jacob Fisher, '17

Mechanical Engineering

Advisor and Direct Supervisor: Daniel Frey, Professor, Mechanical Engineering

Sponsor: Shell International

Vehicle dynamics and design of a rear powertrain and suspension in an electric vehicle

One of the most important components in the conversion of a gasoline vehicle to battery electric power is integrating the electric motor and powertrain into an existing vehicle. A common choice when converting electric vehicles is to use the existing drivetrain with the electric motor and often, the transmission. However, a major challenge to this approach is that the existing drivetrain components might not be rated to the increased torque of the electric motor, and the suspension of the vehicle is not tuned to the added weight of the batteries. The goals of this study are to convert an early 1970s Opel GT to electric power and design a sub-frame that integrates the powertrain components and suspension into the existing vehicle, coordinate placement of batteries and other vehicle components in collaboration with the MIT Electric Vehicle Team, and optimize the ride quality and handling of the vehicle.

Rayna Higuchi, '20

Chemical Engineering
Advisor and Direct Supervisor: Jean-Francois Hamel, Research Engineer, Chemical Engineering

Sponsor: ExxonMobil

Directed evolution of *pseudomonas putida* for degradation of aromatic compounds

Pseudomonas putida is a soil bacterium that is known for its ability to degrade toxic compounds in the environment. However, it does so at the cost of its rapid growth. The goal of my project was to direct the bacteria to evolve to become more efficient at metabolizing these compounds. During the UROP, I set up a closed system for the bacteria to grow in, called a bioreactor, then ran a month-and-a-half long experiment where the *p. putida* grew exclusively on high concentrations of sodium benzoate, a common pollutant. We have not yet concluded our findings, as the project is still running and we have yet to analyze the changes in the bacterium's RNA. From this UROP, I was able to work in a wet lab for the first time, and learn useful techniques for working under different biosafety levels.

Jesse Hinricher, '19

Chemical Engineering
Advisor: Fikile Brushett, Assistant Professor, Chemical Engineering
Direct Supervisor: John Barton, Graduate Student, Chemical Engineering

Sponsor: Chevron

Deconvoluting cell-level losses for redox flow batteries

Renewable sources of energy like solar and wind can meet our global energy needs when coupled with grid-scale energy storage. One such storage technology is redox flow batteries, which are promising due to their durability, performance, and scalability. Understanding mass transfer limitations inherent to this technology is a critical step toward advancing redox flow batteries. To this end, I performed polarization and impedance measurements on a model system using iron as the active species. I used this data to simulate electrochemical species moving within a battery cell. I also performed several analytical measurements on our electrolytes. Finally, I tracked polarization evolution across the entire range of state of charge, a deficit in the redox flow battery literature. I enjoyed working with my supervisor to plan experiments and expand the scope of our project. My UROP furthered my understanding of electrochemistry and my goal of going to graduate school to research batteries.

Mariya Layurova, ’18

Chemical Engineering

Advisor: Tonio Buonassisi, Associate Professor, Mechanical Engineering
Direct Supervisor: Juan-Pablo Correa-Baena, Postdoctoral Fellow, Mechanical Engineering

Sponsor: Philip Rettger ’80

Tin oxide as an alternative electron-transporting layer for perovskite solar cells

I explored a new method of perovskite solar cell fabrication, which utilizes tin oxide as an electron transporting layer (ETL) as a substitute for titanium oxide. Tin oxide exhibits better optical and electrical properties than those of titanium oxide. It is more stable, induces lower current loss, significantly simplifies the fabrication process, and does not require high-temperature processing, thus lowering the costs of production. Different aspects of fabrication—such as chemical deposition bath time and concentrations, sintering temperatures, and deposition methods—have been studied and optimized. The optimized method resulted in more 50% reduction of the ETL fabrication time as well as devices with efficiencies as high as 17-18%. Device fabrication and characterization for this project allowed me to learn and develop numerous new skills including wet chemistry and air-free techniques, current-voltage cell characterization, quantum efficiency, UV measurements, and LabView coding.

Ian McNally, ’20

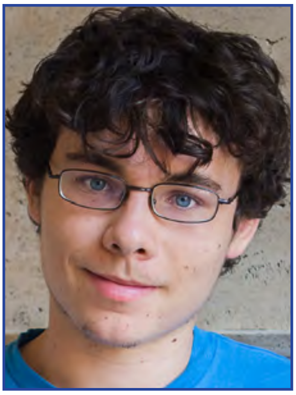
Mathematics

Advisor and Direct Supervisor: John Parsons, Senior Lecturer, Sloan School of Management

Sponsor: Shell International

Analysis of the California congestion revenue rights market

Congestion revenue rights (CRRs) are financial instruments that depend on congestion charges accumulated in the energy grid. Due to the complex nature of these instruments, they are difficult to price and result in disproportionately large payouts to investors. To get to the bottom of this pricing difficulty, I wrote python scripts to build a database and subsequently analyze the data I mined, trying to better understand the CRR market as a whole. I found that the market was much smaller and younger than I expected, which could be causing price inconsistencies. I left this UROP a much better coder and economist, and with a developed interest in financial analysis.



Isaac Metcalf, '20

Materials Science and Engineering

Advisor: Gang Chen, Soderberg Professor and Head, Mechanical Engineering
Direct Supervisor: Thomas Cooper, Postdoctoral Associate, Mechanical Engineering

Sponsor: ExxonMobil

Optimization of revolved compound parabolic concentrators for concentrating solar power systems

The revolved compound parabolic concentrator (CPC) is a 3D solar concentrator with a strict geometric definition that absorbs most, but not quite all, solar radiation within its acceptance angle. During my UROP, I generated spline approximations to the cross section of this revolved CPC in Matlab, and tuned the splines' parameters to search for a similar cross-section with higher absorption efficiency. By the end of the summer, I had raised the efficiency of the concentrator from 95.6% to 97.8%—a small, but meaningful, improvement. I gained a summer's worth of experience with solving engineering problems in Matlab, and was introduced to the fascinating field of nonimaging optics for the first time.

Sai Sameer Pusapaty, '21

Undeclared

Faculty Advisor: Jessika Trancik, Associate Professor, Institute for Data, Systems and Society
Graduate Supervisor: Marco Miotti, Graduate Student, Institute for Data, Systems and Society

Sponsor: John C. Hardwick '92

Robust Projection of Future Light-Duty Vehicle Fuel Economy

My work focuses on predicting the future average fuel economy of various U.S. light-duty vehicles given uncertainties in technological development and consumer preferences. These different vehicle types include gasoline, hybrid, and electric cars. By studying past trends in various vehicle attributes, I aim to develop statistical models using software like R and Python to determine whether the future light-duty vehicle fleet will be able to meet current climate policy targets. I really have enjoyed this experience, from meeting with the rest of the lab group to discussing results with my mentor. I look forward to continuing this project next year.

Puwanat Sangkhapreecha, '18

Chemical Engineering and Biology

Advisor and Direct Supervisor: Jean-Francois Hamel, Research Engineer, Chemical Engineering

Sponsor: Shell International

Rapid quantitative measurement of total fatty acid using nile red dye to study the effect of nitrogen starvation on lipid synthesis in *Chlamydomonas reinhardtii*

My project goal was to use nile red dye to develop a rapid method of quantitatively measuring the total fatty acid in *Chlamydomonas reinhardtii*, instead of using complicated instruments such as gas chromatography. I developed a protocol and implemented it to study the nitrogen starvation effect on lipid synthesis in *Chlamydomonas reinhardtii*. I found that there was an increase in lipid synthesis in the sample growing without nitrogen, and this result was consistent with literature using different techniques. This UROP experience taught me to search for and recognize relevant literature, to work both collaboratively and independently, to be organized, and to be creative in doing research.

Jennifer Switzer, '18

Electrical Engineering and Computer Science

Advisor: Steven Leeb, Professor, Electrical Engineering and Computer Science

Direct Supervisor: Andre Aboulian, Graduate Student, Electrical Engineering and Computer Science

Sponsor: ExxonMobil

A user dashboard for a non-intrusive load monitoring system

For my UROP I worked in the Research Laboratory of Electronics on Non-Intrusive Load Monitoring (NILM). NILM is a novel method of characterizing the energy use of each device in a system using a very small number of electrically non-intrusive sensors. Using this information, combined with prior knowledge of the system being monitored, faults or unusual behavior can be detected. NILM systems have been installed on U.S. Coast Guard (USCG) cutters, providing information that can be used for early fault detection. However, the NILM installations do not currently provide a method for the end users of the system—in this case, the ships' crews, to actually view the collection of information in real time. For my project, I created a user dashboard that provides real-time visibility into the system being monitored, giving the end-users the chance to act on any detected faults as they occur.

Hilary Vogelbaum, '20

Materials Science and Engineering
Advisor: Frank O'Sullivan, Director of Research, MIT Energy Initiative
Direct Supervisor: Ian Miller, Graduate Student, Chemical Engineering

Sponsor: Lisa Doh Himawan '88

A novel tool for parametric life cycle analysis of renewable energy technologies

Renewable energy has been widely promoted as a carbon-free alternative to traditional energy sources. However, in order to objectively compare the carbon impact of energy technologies, we must look at the entire life cycle of a technology. To this end, my project uses life cycle analysis (LCA) to analyze emissions of renewable technologies. LCA is a time-intensive process for each context in which a technology is analyzed. My project addresses this issue by creating a tool that combines published LCAs and derived relationships to immediately analyze life cycle emissions. The tool is able to vary pertinent parameters so that the carbon impact for different contexts can be instantly evaluated. Our tool will help industry members make decisions about technology investments from a carbon emissions perspective. I gained valuable experience working at the intersection of research and industry through this project, and it has reaffirmed my desire to enter the energy industry after MIT.

Ava Waggett, '19

Chemical Engineering
Advisor: William Green, Professor, Chemical Engineering
Direct Supervisor: Mark Goldman, Graduate Student, Chemical Engineering

Sponsor: Chevron

Automated tree generation using machine learning models

The open-source software Reaction Mechanism Generator (RMG) uses kinetics and thermodynamics models to predict reactants, both bulk and trace, in the scale-up of chemical processes. These models are built on existing kinetics and thermodynamics data, typically derived from quantum calculations or experimentation. The work I did this past summer involved the characterization of reactions to determine what features most influence their respective kinetics. Likewise, this afforded me the ability to predict kinetics for reactions with unknown kinetics parameters. To characterize reaction species, I developed a fingerprinting algorithm that captured features of the reaction—atom type, radical, charge, bond number—and represented the presence or absence of particular features within a binary list. These fingerprints were then inputted into machine learning models for estimation of kinetics. Through my experience, I learned how computation can aid in solving chemical engineering problems.

"I gained valuable experience working at the intersection of research and industry through my UROP project, and it has reaffirmed my desire to enter the energy industry after MIT."

— Hilary Vogelbaum '20
Materials Science and Engineering

Meet the 2017 Sponsors

Chevron
Chevron is one of the world's leading integrated energy companies. Its people and their commitment to get results the right way—by operating responsibly, executing with excellence, applying innovative technologies, and capturing new opportunities for profitable growth—drive its success. Chevron is involved in virtually every facet of the energy industry. The company explores, produces, and transports crude oil and natural gas; refines, markets, and distributes transportation fuels and lubricants; manufactures and sells petrochemical products; generates power and produces geothermal energy; provides renewable energy and energy-efficiency solutions; and develops the energy resources of the future, including research into advanced biofuels.

ExxonMobil
ExxonMobil, the largest publicly traded international oil and gas company, uses technology and innovation to help meet the world's growing energy needs. ExxonMobil holds an industry-leading inventory of resources, is one of the largest refiners and marketers of petroleum products, and its chemical company is one of the largest in the world.

A. Thomas Guertin, PhD '60
Alfred Thomas Guertin received his PhD in chemistry from MIT and worked for American Cyanamid Company. He now lives in Palm Coast, Florida.

John C. Hardwick '86, SM '88, PhD '92
John C. Hardwick received SB degrees in aerospace engineering and in electrical engineering and computer science from MIT in 1986. He received SM and PhD degrees in electrical engineering and computer science from MIT in 1988 and 1992, respectively. Hardwick is a co-founder and an owner of Digital Voice Systems, Inc. (DVSI), where he has served as president since the company's incorporation in 1988. He is a major contributor to DVSI's IMBE™* and AMBE®* voice coding technology, and an author of the Inmarsat-M and Mini-M Voice Codec specifications and the APCO Project 25 Vocoder Description (TIA IS-102BABA).

* IMBE and AMBE are trademarks of DVSI.

Lisa Doh Himawan '88

Lisa Doh Himawan received her SB degree in materials science and engineering from MIT in 1988.

Philip Rettger '80

Philip Rettger received his SB in economics from MIT in 1980. He began his career in the energy industry with a UROP project in the late seventies that evaluated the effectiveness of subsidized energy conservation programs with the Massachusetts Energy Office. Following his UROP, Rettger went to work for the same office, and then other companies, in the evaluation, development, and financing of renewable electricity generation projects. He was co-founder of a solar PV company in the early 2000s that resulted in several of the largest solar electricity projects in the world.

Shell International

Shell is a global group of energy and petrochemicals companies with around 101,000 employees in more than 90 countries and territories. In the United States, Shell operates in all 50 states and employs more than 20,000 people working to help tackle the challenges of the new energy future. Shell is a leading oil and gas producer in the deep water Gulf of Mexico, a recognized pioneer in oil and gas exploration and production technology and one of America's leading oil and natural gas producers, gasoline and natural gas marketers, and petrochemical manufacturers.

“My UROP was an opportunity to study the materials science behind the latest breakthroughs in solar cell technology and develop my understanding of what is driving the growth in the solar cell industry.”

— Tahina Felisca ’19
Mechanical Engineering

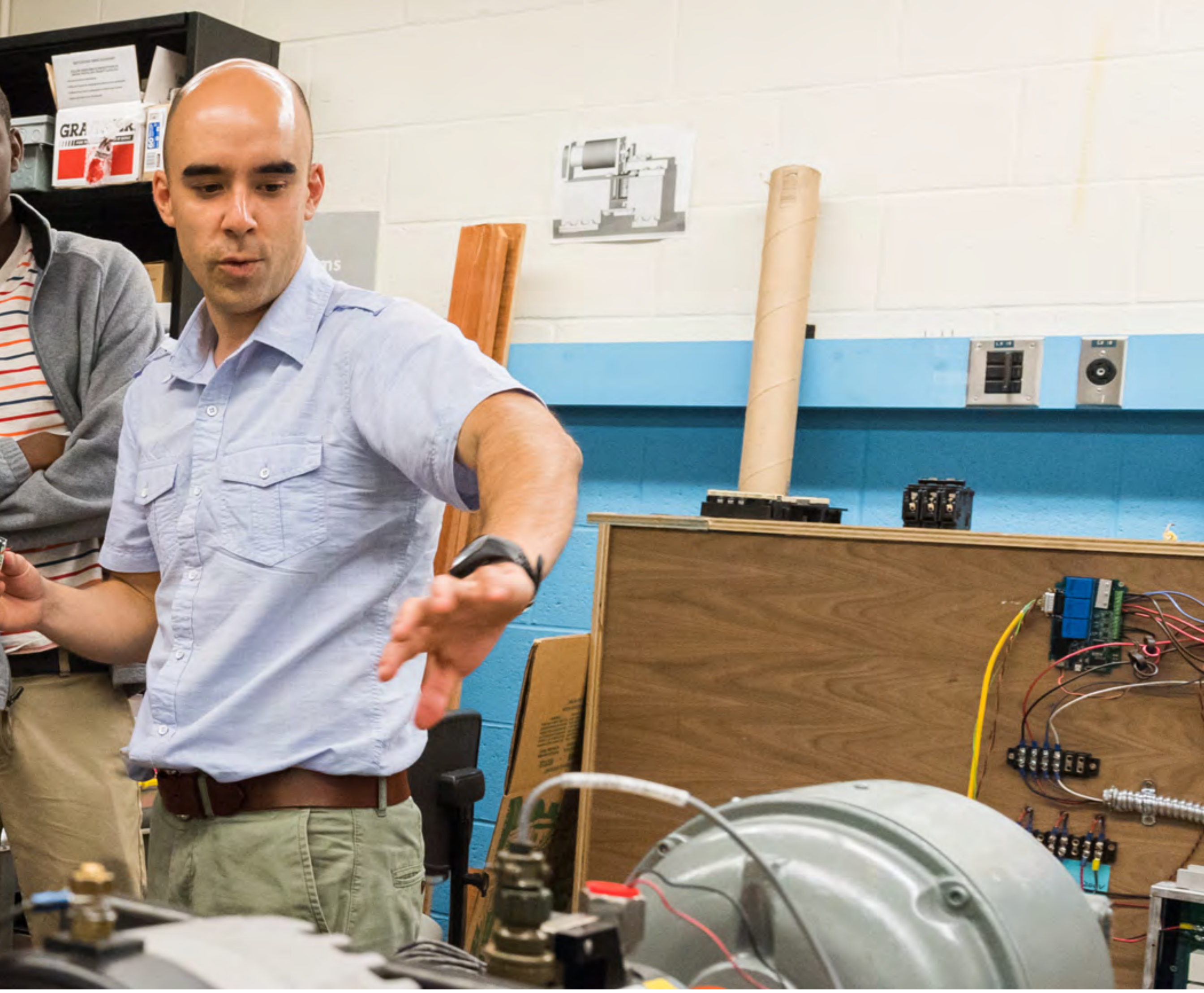
“My UROP has strengthened my understanding of electrochemistry; as a result, I feel more engaged with my school and field.”

— Jesse Hinricher ’19
Chemical Engineering

Sponsor a MITEI UROP

Undergraduate energy research at MIT flourishes with the generosity of donors interested in supporting outstanding students researching a wide range of energy topics. The MITEI UROP Fund is a discretionary gift fund available to all individuals interested in sponsoring MITEI UROP students. MIT staff, alumni, and other friends of undergraduate energy research can make donations in any increment at giving.mit.edu/explore/faculty-research/energy.

Certain levels of donations qualify for MITEI Affiliate Member status, which includes invitations to all MITEI-sponsored events. For more information about sponsoring UROP students, please contact our member services department at energy.mit.edu/contact/#member-services.



“UROPing with MITEI was a great learning experience and provided me with valuable skills applicable in the classroom and the job search alike.”

— Ian McNally ’20
Mathematics

"MITEI's UROP is an indispensable element of the undergraduate experience. It provides a student's first real opportunity to work and think independently as a practicing scientist or engineer."

— Robert James Stoner
Deputy Director for Science and Technology
MIT Energy Initiative

MIT Energy Initiative
77 Massachusetts Avenue, E19-307
Cambridge, MA 02139-4307

energy.mit.edu