Cornell Engineering
Systems Engineering

SYSTEMS Magazine

Fall 2021

SYSTEMS ENGINEERING GRAD COMPETES ON NETFLIX BAKING SHOW

PAGE 3

MESSAGE FROM OUR DIRECTOR

This is certainly an exciting time to be a part of Cornell's Systems Engineering program and I am honored to be part of the leadership of this growing curriculum.

First let me welcome Semida Silveira to our faculty, who joins us as our first Professor of Practice. Semida comes to Ithaca from KTH Royal Institute of Technology in Stockholm where she was a professor in energy systems planning. Between 2007-19, she led the Energy and Climate Studies group at the Department of Energy Technology with a focus on energy and sustainable development. She will be instrumental in helping to guide the new energy systems specialization in our M.Eng. degree program.

Two of our recent graduates made news earlier this fall. Faisal Alkaabneh '20, the first to earn his Ph.D. in Systems from Cornell, was named an Intel Faculty Fellow for 2021-22. Faisal, who is now an assistant professor at North Carolina A&T State University, will be working to contribute to the advancement of food bank operations efficiency by optimizing allocation and inventory management. This is extremely prudent work during a time when food banks are being stressed throughout the country.

Renee Frohnert M.Eng. '19 appeared on Netflix's Baking Impossible, an eight-episode series that paired bakers and engineers in timed competitions. The "bakineers" were required to meet cooking, design and engineering challenges.

And, of course, our faculty continues to do impressive and important research. Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering, is using systems-level modeling and optimization to inform decisions on campus energy systems for carbon neutrality. Professor You, along with Cornell Engineering Dean Lynden Archer, led a study to identify ways to sustainably manage the influx of expired EV batteries, focusing on battery chemistry, second-life applications and recycling.

Three of our current doctoral students also received good news. Ning Zhao recently took runner-up honors for the De Gruyter Best Paper Award at the PRES'21 conference held in the Czech Republic in October, while fellow Ph.D. student Shiang-Wan Chin was named a Rockey Foundation for Food and Agriculture Fellow for 2021-24. And Christian Sprague has been named the U.S. Department of Transportation's University Transportation Centers Program and the Council of University Transportation Centers 2022 Student of the Year, while also being awarded Cornell's Center for Transportation, Environment, and Community Health 2022 Ph.D. Dissertation Award and the Cornell Center for Social Sciences 2022-23 Data Science Fellowship.

With warm regards,

H. Oliver Gao
Director, Systems Engineering

Fall 2021

Systems Magazine is published by the Systems Engineering Program at Cornell University

Director: H. Oliver Gao
Interim Program Manager: Sheri Minarski

Writers: Blaine Friedlander, Patrick Gillespie, Olivia M. Hall, Syl Kacapyr, David Nutt, Joe Wilensky

Editors: Patrick Gillespie, H. Oliver Gao, Reeve Hamilton, Syl Kacapyr

Designer: Patrick Gillespie

Photography: E. Jacob Cornelius, University Photography, Robyn Wishna

ON THE COVER
Renee Frohnert M.Eng. '19 competed on the Netflix original series Baking Impossible, which combined baking with engineering.

THE SYSTEMS MISSION
The mission of the Cornell Systems Engineering Program is to educate students and to stimulate intellectual achievement in the discipline of systems engineering across numerous application domains.

Cornell University
Systems Engineering
601 Frank H.T. Rhodes Hall
136 Hoy Road
Ithaca, NY 14853
607.255.4856

ENGINEERING ALUMNA ROCKETS TO NETFLIX BAKING COMPETITION

For her audition video for Netflix's new baking-engineering competition show "Baking Impossible," Renee Frohnert, M.Eng. '19, baked a batch of cupcakes and took a bite out of one, then attached it to a rocket, which she proceeded to launch nearly 400 feet into the air. The demonstration—which she introduced by first assembling the rocket—was meant to show her engineering acumen, creativity, and basic baking skills for what she excitedly announced as "space cakes!"

While the cake-and-rocket combo didn't quite leave Earth's atmosphere (it likely landed on the roof of a nearby building, she says), the audition—and Frohnert's passion for the assignment—did garner her a spot on the show, which premiered on the streaming service in early October. The eight-episode series pairs bakers and engineers in timed competitions that require their creations to meet both cooking, design and engineering challenges.

Nine baker-engineer paired teams (dubbed "bakineers")—who had never met before—had to quickly figure out how to work together and harness their separate skill sets, while keeping design, taste, innovation, and structural soundness in mind for each challenge.

"For me, the entire experience, especially coming from the engineering world, was really eye-opening," says Frohnert, who was paired with Steve, a 62-year-old professional baker from Florida. "I didn't realize how much engineering actually goes into baking."

For the first challenge, the teams had nine hours to build a cake-based boat—at least two feet long with at least one sail, a 4.8-volt servo motor, and a rudder—that would have to navigate a 20-foot water course in less than 45 seconds in 7 knots of wind. Frohnert and Steve decided to use chocolate for the entire exterior of the boat due to its waterproof properties.

Frohnert (right) and her teammate, a baker from Florida. (Photo: Netflix/provided)

Frohnert says she and Steve both had to "really quickly jump in and learn from each other." Steve gave her a crash course in how to temper chocolate, and she ended up tempering 50 pounds of it for their boat. In return, she taught him how to calculate buoyancy and water displacement. Their boat floated beautifully, a testament to its engineered structure (not everyone's crafts stayed upright), although the water course itself posed additional hurdles.

For subsequent challenges, Frohnert had to design—and redesign—numerous engineered machines and elements for assignments like creating a wearable and edible fashion piece for a runway show; a playable miniature golf course made from dessert materials; and a baked cityscape featuring a five-foot-tall skyscraper that would be put to the test of withstanding a simulated earthquake on a shake table.

The show's time constraints and other entertainment-focused parameters necessitated skipping a lot of what would typically be extensive design and testing phases for any engineer, going "straight to the build phase," she explains—something very different from the typical rigorous process of systems engineering. "But

ultimately, it also got me out of my comfort zone, which can be really important."

Frohnert showed a keen interest in engineering from an early age. At seven, she learned from her dad how to take a car transmission apart, clean it, and reassemble it, and she worked on cars in their garage throughout her childhood.

She got her undergraduate degree in electrical engineering at Penn State and was hired at Lockheed Martin Space. She entered the company's engineering leadership development program and headed to Silicon Valley, where she worked on electrical components for the Orion spacecraft as part of NASA's Artemis program, which aims to establish a sustainable presence on the Moon to prepare for human exploration missions to Mars.

While continuing to work full time, she enrolled in Cornell's systems engineering master's program as a distance-learning student. In the meantime, Frohnert had found an additional interest—speaking to groups about aerospace and spacecraft, and about how women can thrive within traditionally male-dominated STEM (science, technology, engineering, and mathematics) disciplines. She has more than 15,000 followers on Instagram, many of them "women in STEM who are trying to navigate the field," Frohnert says.

Frohnert (right) and teammate Steve Day of Boca Raton, Fla. compete in one of Baking Impossible's challenges. (Photo: Netflix/provided)

She discovered this calling at Penn State, where, as one of only three women out of about 200 students in the electrical engineering program, she joined the Society of Women Engineers. At Cornell, she was thrilled to find a far more equal gender balance.

Cornell Engineering hit a much-publicized milestone right around that time: in fall 2018, women comprised half of the incoming undergraduate Class of 2022. It was the first engineering college of its size—and stature—to reach gender parity. "That was a huge stat—I was so proud," Frohnert says.

Frohnert (left) celebrates a successful challenge in the first round.

Today, Frohnert works for L3Harris Space & Airborne Systems business development group in San Diego while pursuing an MBA at the University of Southern California, focusing on entrepreneurship and business leadership.

Frohnert says she would eventually like to start her own engineering or aerospace business, create some type of nonprofit to inspire and support women and other underrepresented communities in STEM, or even develop a kids' TV show—no word yet on whether it will include a bakineering competition.

By Joe Wilensky

SYSTEMS FACULTY NEWS

PROFESSOR JEFF TESTER ELECTED TO NAE

Jefferson W. Tester, the Croll Professor of Sustainable Energy Systems, School of Chemical and Biomolecular Engineering, has been elected to the National Academy of Engineering for leadership in development of novel renewable energy systems.

Election to the National Academy of Engineering is among the highest professional distinctions accorded to an engineer. Academy membership honors those who have made outstanding contributions to "engineering research, practice, or education, including, where appropriate, significant contributions to the engineering literature" and to "the pioneering of new and developing fields of technology, making major advancements in traditional fields of engineering, or developing/implementing innovative approaches to engineering education." Election of new NAE members is the culmination of a yearlong process. The ballot is set in December and the final vote for membership occurs during January.

Tester was among 104 new members elected and 24 international members, announced by NAE President John L. Anderson. This brings the total U.S. membership to 2,353 and the number of international members to 299. Individuals in the newly elected class were formally inducted during the NAE's annual meeting on October 3, 2021.

Professor Jefferson Tester

JAHANI, TEO JOIN SYSTEMS AS LECTURERS

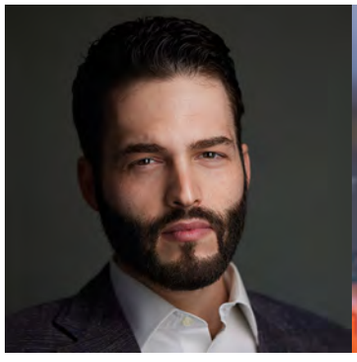
The systems engineering program is pleased to announce the appointments of two new lecturers—Joshua Jahani and Zhiyuan (Z.) Teo—for the spring 2022 semester.

Jahani earned his Master of Engineering in systems engineering from Cornell University in 2012 and teaches courses on strategy, finance, and entrepreneurship at New York University. Jahani began his career at Deloitte in 2012 as strategy advisor. He specialized in transaction advisory for some of the world's largest companies. This gave him exposure and expertise in the complex world of global capital markets.

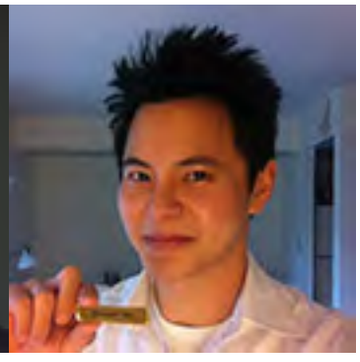
He is now the managing director of Jahani and Associates (J&A)—an investment bank based in New York City with presence in Singapore and Abu Dhabi. J&A was started in 2018 to provide value in the largely underserved middle market cross border transaction sector, specifically focused on emerging markets.

Zhiyuan Teo is a software engineer with Google Finance Works in New York City and CEO of Ironstack, a tech startup that builds modern, intuitive and frustration-free computer network management solutions. He earned his Ph.D. in computer science from Cornell in August 2016.

Teo's research is primarily applied in style and centered around practical aspects of software-defined networking. As a graduate student, he built a distributed OpenFlow controller that drove the computer science department's operational data network. At its peak, the controller managed a network of 400 physical and virtual hosts, providing connectivity to over 1,000 students, faculty and researchers. The software has been in continuous, outage-free operation since June 2015.



Joshua Jahani



Zhiyuan Teo

SYSTEMS FACULTY NEWS

YOU RECEIVES NATIONAL AWARD ON SUSTAINABILITY EDUCATION

Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering, was selected to receive the 2021 Sustainable Engineering Forum Education Award from the American Institute of Chemical Engineers (AIChE) to recognize his contributions and accomplishments on sustainability education.

AIChE is the world's leading organization for chemical engineering professionals, with more than 60,000 members from over 110 countries. The Sustainable Engineering Forum Education Award recognizes and honors an educator who has made outstanding contributions to sustainability education. Professor You was recognized for his contributions of integrating sustainability science into the undergraduate and graduate curriculum at Cornell and other institutions around the world, developing life cycle assessment (LCA) educational modules and materials, and training students through project teams on sustainable process design, LCA, sustainable campus, decarbonization, renewable transition, and sustainable energy systems analysis.

SEF
Sustainable Engineering Forum
An AIChE Community

FENGQI YOU ADMITTED AS A FELLOW OF FRSC

Professor Fengqi You, the Roxanne E. and Michael J. Zak Professor in in Energy Systems Engineering, has been admitted as a Fellow of the Royal Society of Chemistry (RSC). RSC is a U.K.-based professional society founded in 1841 with over 50,000 members worldwide, and it is the largest organization in Europe for advancing the chemical sciences.

The designation Fellow of the Royal Society of Chemistry (FRSC) is an award conferred by the RSC and is given to elected Fellows who have made significant contributions to the chemical sciences. FRSCs hold positions of influence in the community and have invaluable experience, expertise, and commitment to promoting the value of chemical science. Achieving Fellow status in the chemical profession denotes a high level of accomplishment as a professional chemist to the broader community.

RSC's mission is:

- To enable change in chemical science education and practice to ensure a diverse and skilled workforce.
- To provide the opportunities and tools for the chemical science community to network, create and exchange knowledge, adapt and thrive.
- To recognize and reward innovation, collaboration, teamwork and leadership, and uphold ethical and professional standards.
- To be a trusted and authoritative voice, ensuring that chemistry has a recognized and influential role in science and society.

Professor Fengqi You

SEMIDA SILVEIRA BECOMES SYSTEMS' FIRST PROFESSOR OF PRACTICE

Our program continues to grow!

H. Oliver Gao, the director of the Systems Engineering Program and the Howard Simpson Professor in the School of Civil and Environmental Engineering, is pleased to announce that Semida Silveira will join the program as its first Professor of Practice in January.

Silveira comes to Cornell from KTH Royal Institute of Technology in Stockholm where she is a professor in energy systems planning. Between 2007 and 2019, she led the Energy and Climate Studies (ECS) group at the Department of Energy Technology with a focus on energy and sustainable development.

"I am thrilled by the opportunity to join the Systems Engineering team at Cornell University," said Silveira. "The transdisciplinary approach of the program provides a solid base for designing and implementing sustainable solutions to the problems of modern society. I want to contribute with research, education and leadership to enhance our impact."

"The growing energy needs of the world and the threats brought on by climate change are the greatest grand challenges of the 21st century with potential impacts that extend for generations to come," Gao says. "To address these challenges head on, together with the Cornell Energy Systems Institute (CESI), the Cornell Systems Engineering program has launched a new Energy Systems Specialization in our M.Eng. degree. This degree and specialization are dedicated to developing students as leaders who will create complete solutions that are sustainable, responsible and socially achievable.

"With the broad range of stakeholders' needs, technology and societal impacts, energy is truly a systems problem. I am excited that Professor Silveira is joining Cornell Systems at this critical time of challenges and opportunities," continues Gao. "As a world leader in energy systems with her unique combination of transdisciplinary background, versatile experience and profound enthusiasm, Professor Silveira is ideally positioned to connect and integrate energy systems engineering, planning and policy and practice for systems innovations and impacts."

Professor Silveira has a professional degree in architectural engineering from the Federal University of Minas Gerais (UFMG) in Brazil and a Ph.D. in regional planning from KTH, with a focus on development and sustainability. Previously, she worked as a sustainability expert at the Swedish Energy Agency and as an energy and climate program manager at the Stockholm Environment Institute. Her most recent activities include bioenergy and climate change policy work, energy and development, energy efficiency in industries, urban sustainability, promotion of Swedish knowledge and technologies, and international business cooperation with corporate responsibility.

Systems' first Professor of Practice, Semida Silveira

Professor Silveira won the 2001 Jaboti Literature Prize in Brazil in the category physical sciences, technology and informatics for her book "Electricity for Sustainable Development," published in Portuguese. She is also the author of dozens of scientific articles, popular science articles and books including an anthology of the Swedish energy development, "Building sustainable energy systems—Swedish experiences," and the book "Bioenergy—realizing the potential."

She has done research at MIT, International Institute for Applied Systems Analysis (IIASA), University of Tübingen and University of Stockholm, and advised in various committees and board of directors of Swedish companies.

In the early 1990s, Silveira launched the first master's program with sustainability focus at KTH (Environmental Engineering and Sustainable Infrastructure)—this was also the first program in English aimed at global recruitment at KTH. The program is still running. More recently, together with the department of industrial economy, Professor Silveira developed a new profile and courses for engineer students at KTH with a focus on energy and climate policy design and implementation, as well as management from multiple stakeholder perspectives.

Professor Silveira has developed and managed projects in collaboration with academics, multilateral organizations, policy makers and the private sector in both industrialized and developing countries in Latin America, Africa and Asia.

SUSTAINABILITY EFFORTS SHINE WITH NEW SOLAR COLLECTORS

For proof that the pandemic has not stopped campus sustainability efforts, look no further than the rooftop of Guterman Research Center.

The center on Caldwell Road—which houses research and teaching labs, growth chambers, controlled atmosphere storage rooms and greenhouse facilities—has installed 50 new solar collector panels. The system uses an innovative mirror technology, as opposed to conventional photovoltaic cells, to capture sunlight and turn it into thermal energy that will help heat the facility's water distribution network and reduce its reliance on campus steam.

The new solar thermal system is expected to annually reduce the Guterman facility's campus steam consumption by 122 million BTUs and offset approximately 4% of the facility's summer heat load.

It's one of several sustainability projects, from reusable dining serviceware to living laboratory experiments, that are continuing apace despite the many interruptions made by COVID-19 to campus life.

The intelligent mirror array is the first of its kind at Cornell and the seventh on-campus solar system, with construction of an eighth project set to commence on North Campus in June. The Guterman Research Center now joins the Nevin Welcome Center at Cornell Botanic Gardens and the Combined Heat and Power Plant as the only sites of solar thermal systems on the Ithaca campus.

The Guterman facility was an ideal choice because it has a constant, year-round demand for heating, according to Matt Kozlowski, civil and environmental engineering manager in Facilities Engineering.

"That's not necessarily typical of the rest of campus," Kozlowski said. "So it was a good match."

A new solar collector system installed atop Guterman Research Center uses innovative mirror technology to capture sunlight and turn it into thermal energy that will help heat the facility's water distribution network. (Lindsay France/Cornell University)

The system is expected to annually reduce the facility's campus steam consumption by 122 million Btus and offset approximately 4% of the facility's summer heat load. It was designed, installed and will be maintained by Skyven Technologies, grand prize winner of the 76 West clean-energy technology competition in 2017, with the support of a New York State Energy Research and Development Authority (NYSERDA) Ignition Grant.

"This is directly offsetting fossil fuel use, with the potential, in the future, that this ties into a district energy system fueled by Earth Source Heat or some other kind of renewable technology," Kozlowski said. "There are all these different interesting sources. This is another piece of that puzzle."

Planning for the system, which is set to go online in early April, began well before the pandemic. The installation process was slow but steady, with a small team of one to four people, usually an engineer installer and occasionally a handful of roofers, working through the winter.

"It was something that kept us steadily moving forward, even during a time when many projects were put on hold and everyone was navigating challenges of a new pandemic," said Rhoda Maurer, manager of the Cornell Agricultural Experiment Station Plant Growth Facilities. "This is essentially moving us in a direction where we can look at, and contribute towards, the development of new technologies that are going to help Cornell with its long-term carbon neutrality goals, but also help the larger world."

"This project also specifically helps Cornell AES meet some of our unit sustainability goals by piloting new agricultural technologies that could benefit

New York farmers," Maurer said.

The system is the first in a series of long-planned sustainability projects at the Guterman center that include modernizing its greenhouses and growth chambers.

Living labs and reduced landfill waste

An additional benefit of the intelligent mirror array is its potential to function as a living laboratory for student and faculty sustainability research, Kozlowski said.

It certainly has plenty of company. A number of living lab projects with a sustainability focus are in progress this semester.

For the capstone senior seminar in Environment and Sustainability course, student teams are evaluating 20 years of data related to the university's Lake Source Cooling, with an emphasis on analyzing its energy and greenhouse-gas savings, economic return on investment, lake impacts and outreach to the Ithaca community.

Another project, led by Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering, is using systems-level modeling and optimization to inform decisions on campus energy systems for carbon neutrality. You's research team is particularly interested in assessing the challenges that arise from the fluctuations of energy demand, both by season and the daily cycle of electricity consumption, with Lake Source Cooling and Earth Source Heat.

"Systems level optimization is important to ensure we select the best energy technologies and systems that would be cost-effective, energy efficient and environmentally sustainable, as our campus transitions to carbon free," You said. "Rigorous quantitative analysis based on systems optimization would also help to address the short-term fluctuation, seasonality and resilience issues."

Other recent sustainability initiatives don't rely on data and modeling, but rather cutlery and working groups.

Cornell Dining launched a new partnership to reduce the price of reusable utensil and takeout container sets with the goal of preventing more than 900 disposable containers from ending up in the landfill each day.

Cornell Dining launched a new partnership on March 1 with the Campus Sustainability Office and Cornell Grounds to provide members of the campus community a discount on reusable utensil and takeout container sets. The sets, which normally cost $12, are available for $5. The effort seeks prevent more than 900 disposable containers from ending up in the landfill each day.

And the Sustainable Cornell Council is overseeing a variety of committee efforts, from optimizing purchasing inventory to encouraging student sustainability literacy.

While the pandemic has taken a toll that has yet to be fully calculated, one positive development has emerged. The drop in commuting and business travel, as well as reduced operations, helped put a dent in the university's campus carbon footprint, which dropped 20% from 2019 to 2020, and 49% from the 2008 baseline.

By David Nutt

The new solar thermal system is expected to annually reduce the Guterman facility's campus steam consumption by 122 million Btus and offset approximately 4% of the facility's summer heat load. (Lindsay France/Cornell University)

NEW YORK STATE'S CLIMATE GOALS ARE ACHIEVABLE, RESEARCH FINDS

New York state has set ambitious climate goals. It has committed to using 100% carbon-free electricity by 2040. And it's pledged to reduce its total carbon pollution by 85% percent below 1990 levels within the next three decades.

"So these are very aggressive targets," says Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering.He wanted to figure out if these goals are realistic.

"Before we started this study, we were not sure," You says.

Professor You's team analyzed scientific and economic data and concluded that the goals are technologically and financially feasible. And the researchers provided a road map to achieve them.

It relies heavily on off-shore wind for electricity.

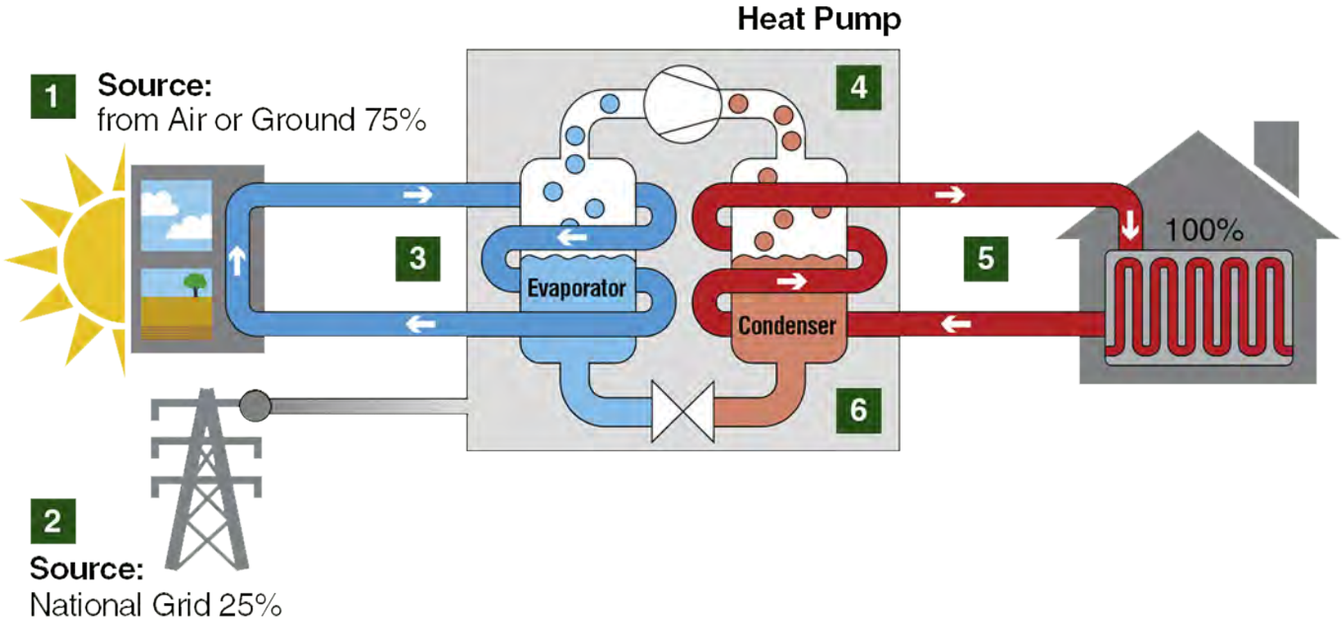
For heating homes and buildings, You says the state will probably still rely on natural gas for a decade or more. But after that, he says natural gas furnaces can be phased out in favor of electric heat pumps, which extract heat from the air or ground.

Professor You says that if the state invests in these technologies, it can meet its goals. And if it also implements a carbon tax, it could even meet these goals ahead of schedule.

"So in the end, we do see the future is quite bright," he says.

… as long as New York starts making changes now.

Reporting credit: Sarah Kennedy/ ChavoBart Digital Media.



RECYCLING NEXT-GENERATION SOLAR PANELS FOSTERS GREEN PLANET

Tossing worn-out solar panels into landfills may soon become electronics waste history.

By designing a recycling strategy for a new, forthcoming generation of photovoltaic solar cells—made from metal halide perovskites, a family of crystalline materials with structures like the natural mineral calcium titanate—will add a stronger dose of environmental friendliness to a green industry, according to Cornell-led research published June 24 in "Nature Sustainability".

The paper shows substantial benefits to recycling perovskite solar panels, though they are still in the commercial development stage, said Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering in the College of Engineering.

A solar cell made with perovskite (image to the right) shows promise as an energy-efficient, scalable and longer-lasting way to create solar panels—and may be recycled for even greater sustainability.

"When perovskite solar panels reach the end of their useful life, how do we deal with this kind of electronic waste?" said You, also a faculty fellow at the Cornell Atkinson Center for Sustainability. "It is a new class of materials. By properly recycling it, we could potentially reduce its already low carbon footprint.

"As scientists design solar cells, they look at performance," You said. "They seek to know energy conversion efficiency and stability, and often neglect designing for recycling."

Last year, You and his laboratory found that photovoltaic wafers in solar panels containing all-perovskite structures outperform photovoltaic cells made from state-of-the-art crystalline silicon, and the perovskite-silicon tandem—with cells stacked like pancakes to better absorb light—perform exceptionally well.

Perovskite photovoltaic wafers offer a faster return on the initial energy investment than silicon-based solar panels because all-perovskite solar cells consume less energy in the manufacturing process.

A solar cell made with perovskite. (Dennis Schroeder/National Renewable Energy Laboratory)

Recycling them enhances their sustainability, as the recycled perovskite solar cells could bring 72.6% lower primary energy consumption and a 71.2% reduction in carbon footprint, according to the paper, "Life Cycle Assessment of Recycling Strategies for Perovskite Photovoltaic Modules," co-authored by Xueyu Tian, a Cornell Systems doctoral student, and Samuel D. Stranks of the University of Cambridge.

"Lowering the energy needed to produce the cells indicates a significant reduction of energy payback and greenhouse gas emissions," said Tian.

The best recycled perovskite cell architecture could see an energy payback time of about one month, with a carbon footprint as low as 13.4 grams of carbon dioxide equivalent output per kilowatt hour of electricity produced. Without recycling, the energy payback time and carbon footprint of new perovskite solar cells show a range of 70 days to 13 months, and 27.5 to 158.0 grams of carbon dioxide equivalent throughout their life cycles.

Today's market-leading silicon photovoltaic cells can expect an energy payback period of 1.3 to 2.4 years, with an initial carbon footprint between 22.1 and 38.1 grams of carbon dioxide equivalent emissions per kilowatt hour output.

"Recycling makes perovskites outcompete all other rivals," Tian said.

Informed state and federal policies, along with recycling infrastructure development strategies, can further mitigate the environmental impacts in making photovoltaic solar cells.

"The real value of an effective green perovskite solar panel industry may rely on a recycling program," You said.

The National Science Foundation supported this research.

By Blaine Friedlander

STUDY PROVIDES KEYS TO MANAGING INFLUX OF EV BATTERIES

As electric vehicle production revs up across the globe, an inherent consequence will be the mutually growing number of retired lithium-ion batteries that, unlike traditional lead-acid car batteries, are difficult to dispose of.

A new Cornell-led study identifies several keys to sustainably managing the influx, with an emphasis on battery chemistry, second-life applications and recycling.

"What to do with all these retired electric vehicle batteries is going to be a huge issue," said Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering, who used advanced modeling to examine environmental and economic tradeoffs in how batteries are built, used and recycled.

The life-cycle analysis, which considered a variety of options for battery materials and technologies, is detailed in research published Nov. 5 in "Science Advances".

From the very beginning of a battery's life cycle, when its raw materials are mined from the Earth, economics drive decisions about how the battery is built.

"Lithium-ion batteries are designed today for performance and not for recycling or second life," said You, noting that electric vehicle batteries typically last five to 12 years before they lose the energy capacity needed to power a vehicle. "There's very little discussion right now about these environmental dimensions of improving battery design for recycling or reuse."

One finding is that a battery's chemistry can affect its overall environmental impact. For instance, cobalt is a common battery material that, when mined, is energy-intensive and damaging to the environment. Replacing cobalt with nickel can alleviate those concerns, but most life cycle scenarios reveal there are tradeoffs.

A new Cornell-led study identifies several keys to sustainably managing the influx, with an emphasis on battery chemistry, second-life applications and recycling.

"Cobalt's presence, even at relatively small amounts, in a battery cathode leads to a much less oxidative environment for other components, extending the lifespan of the battery and increasing options for second-life use and materials recycling," said Lynden Archer, the Joseph Silbert Dean of Engineering and co-author of the study.

But, Archer said, cobalt's expense—and association with exploitative child labor—has led the material to be "conventionally thought of as undesirable in the low-cost batteries needed for an 'electrify-everything' future."

The analysis also found that an electric vehicle battery's overall carbon footprint can be reduced by up to 17% if it can be reused before it is recycled. One choice for battery reuse is power stations that store wind and solar energy. Such energy storage is growing in demand and can make use of retired batteries with reduced energy capacity. And as the share of renewable energy contributing to the power grid grows, a reused battery's carbon footprint shrinks by around a quarter.

Most of today's recycling facilities have difficulty breaking apart heavily fortified car batteries and recovering the raw materials within. Yanqiu Tao, a doctoral student who co-authored the study, said policymakers should consider ways to incentivize recycling techniques that optimize the battery's sustainability.

"In the study we consider the commonly used graphite as the anode-active material, which is hard to recycle and emits carbon dioxide when it's combusted," Tao said. "If policymakers can promote graphite separation or emerging recycling methods, it would reduce the environmental impact."

Also co-authoring the study was Christopher Rahn, associate dean for innovation at the Pennsylvania State University College of Engineering.

By Syl Kacapyr

LONG COMMUTES, HOME CROWDING TIED TO COVID TRANSMISSION

Long commute times and household crowding may be good predictors for a higher number of transmissible coronavirus cases in metropolitan settings, according to Cornell urban planning, architectural and public health researchers, in a July study published in the journal "Buildings and Cities".

Neighborhoods that had populations with predominantly longer commute times to work—from about 40 minutes to an hour—were more likely to become infectious disease hotspots, the research said.

"We are trying to determine how the built environment influences coronavirus propagation," said senior author Timur Dogan, a systems field member and an assistant professor of architecture in the College of Architecture, Art and Planning.

"We found that high residential density and high percentage of people commuting by public transit do not relate to a higher COVID-19 case rate," Dogan said. "Household overcrowding and longer commute times appears to impair the pandemic resilience of individual families, medically vulnerable communities and cities, as a whole."

The study, "Urban Design Attributes and Resilience: COVID-19 Evidence from New York City," was published to offer guidance for short-term responses in the safe recovery from the COVID-19 crisis, as well as long-term urban design and planning decisions for a resilient, inclusive and sustainable urban environment in future public health emergencies.

In-home crowding and urban density are two related, but different concepts, when considering pandemic-resilient design and planning. Crowding indicators, which include the number of units per building and the number of occupants per room, correlate with coronavirus transmission, according to the paper.

Neighborhoods that have populations with predominantly longer commute times to work are more likely to become infectious disease hotspots, according to the report.

Neighborhood residential density, on the other hand, was not related to the daily COVID-19 case rate in New York City, as high density often entails other beneficial urban features that are advantageous for the pandemic resilience.

"High-density neighborhoods aren't necessarily bad from a disease transmission perspective," said Dogan. "A well-mixed neighborhood in a city could be beneficial."

The group used ZIP code tabulation area data, and then combined it with other available urban information, to determine how population density and crowding affected infection rates, and how the spatial distribution of points of interest—such as grocery stores, shopping centers and parks, for example—impacted infection rates.

The points of interest-related mobility data in this study was derived by a computer-aided design software utility called Urbano, developed by lead author Yang Yang, a doctoral student in systems engineering and a design researcher at Dogan's Environmental Systems Lab.

"The Urbano software assists with collecting, simulating, and analyzing urban mobility data," Yang said. "It allows mobility-aware decision-making for designers and planners in building a sustainable and resilient city."

Said Dogan: "This is where we start the idea of the 20-minute city, a concept where a person can fulfill all the daily errands, work and daily needs within a 20-minute walk or bike ride."

"This kind of urban design paradigm promises benefits that make our cities more livable, sustainable and resilient," he said. "Professional urban planners say that active mobility is a healthy thing to do. If we can reduce vehicle traffic, we can reduce pollution and reduce energy demand, we can get a healthier population."

By Blaine Friedlander

SYSTEMS' FENGQI YOU CO-AUTHORS PAPER ON QUANTUM COMPUTING

Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering, and Techinical University of Denmark (DTU) researchers are exploring potential applications in chemical and biomolecular design to develop better products and chemical processes to the industry with the application within formulations, catalysis, drug discovery and process operation.

For years, computer-aided methods and tools to develop new processes have been used in chemical process design with great success. Now, new types of computing such as quantum computing are getting more and more attention due to their potential superiority when it comes to problem solving within different areas.

In a recent research paper on new quantum computing application areas, researchers at DTU Chemical Engineering are exploring the link between quantum computing and chemical and biomolecular product and process design. The hope is to develop products and chemical processes that are far more efficient, economic, and sustainable than when using traditional computers.

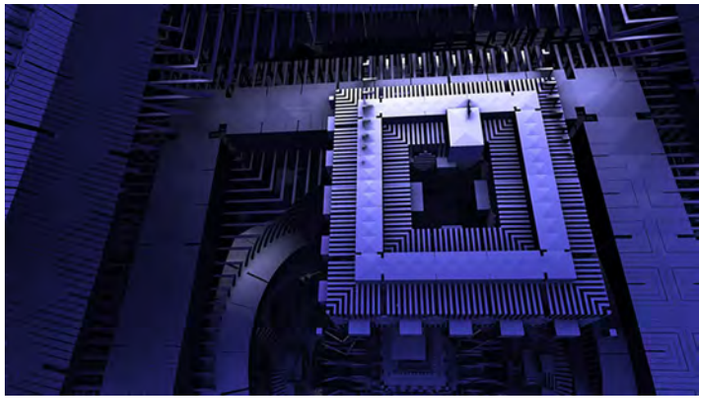
"Quantum computing can potentially find application in tackling some of the most complex problems within chemical and biological engineering. However, work needs to be done to map and explore the potential application areas and how we can leverage the foreseeable abilities of such computations," says Seyed Mansouri, associate professor at DTU Chemical Engineering and lead author of the paper.

"While current quantum computers still lack the capacity for solving industrially relevant problems within quantum chemistry, the technology develops very fast. We are identifying key areas where we see applications being viable in the near future, to be able to take advantage of upcoming quantum computing power in an optimal way," said Martin Andersson, associate professor at DTU Chemical Engineering.

The quantum nature

Quantum computing is not a new field as it has been an active research area since the 1980s. Quantum computing is based on quantum physics and can solve problems that normal or traditional computers cannot due to the quantum nature.

A traditional computer is based on a binary system where information is stored in bits represented by a "0" or "1". While traditional computers can deliver fast calculations, they are still limited when it comes to larger calculations as the speed is reduced significantly as the problem size increases. However, quantum computers are based on qubits. While data in traditional computers are either off or on, the qubits can be off and on simultaneously—also known as a superposition. This makes quantum computing capable of addressing many challenging problems within design of catalysts, protein folding, solvent design and process monitoring and control; thus opens up to a world of possibilities.



Quantum computing: A new paradigm in chemical and biological manufacturing

"Although we have not yet reached the advent of general-purpose quantum computing hardware, there are already some impactful applications in process manufacturing and energy systems that could be addressed through the hybrid quantum-classic computing framework. Quantum computing won't entirely replace classical computing in the foreseeable future, but the technologies have great potential of offering speed-ups and advantages in industrially-relevant applications on computer-aided design, operational optimization, real-time monitoring, and control," says You.

Courtesy of Lonnie Moldt Jørgensen, DTU

TRANSPORTATION INNOVATIONS COULD BOOST PUBLIC HEALTH

Researchers say the future of transportation will be shaped by three "revolutions"—vehicle electrification, driverless cars and ride-sharing—that could result in fewer automobiles on the road, less fossil fuels extracted from the Earth and less pollution in the air. While the environmental gains may seem self-evident, the health benefits are difficult to quantify.

Now for the first time, a Cornell-led team has used transdisciplinary systems modeling to calculate those health benefits in the United States. By 2050, these innovations could potentially slash petroleum consumption by 50% and carbon dioxide emissions by 75% while simultaneously preventing 5,500 premature deaths, with an annual savings of $58 billion.

"There are all these important emerging trends in the development of transportation, and they are becoming a reality in the near future," said Oliver Gao, the Howard Simpson Professor of civil and environmental engineering in the College of Engineering, who led the project.

"Have you ever thought about what all these revolutions mean for your health, for our climate, and for our environment, and for our energy systems?" Gao said. "These externalities don't necessarily come directly in the mind of the general public, the travelers, or even the decision-makers."

The group's paper, "Shared Use of Electric Autonomous Vehicles: Air Quality and Health Impacts of Future Mobility in the United States," published June 26 in Renewable and Sustainable Energy Reviews. The paper's lead author is former postdoctoral researcher Shuai Pan.

"It is worthwhile to understand the effectiveness of these mitigation strategies, as deep de-carbonization is needed in the transportation sector," Pan said.

The future of transportation will be shaped by three "revolutions"—vehicle electrification, driverless cars and ride-sharing—that could result in fewer automobiles on the road, less fossil fuels extracted from the Earth and less pollution in the air., researchers say.

Co-authors include Lewis M. Fulton from the University of California, Davis, and Yunsoo Choi and Jia Jung from the University of Houston. The research was supported by the U.S. Department of Transportation's Center for Transportation, Environment and Community Health, and by Nanjing University of Information Science and Technology.

While previous studies have looked at certain facets of transportation innovation, such as the impact of electric vehicles on fuel usage and emissions, this is the first time anyone has employed a transdisciplinary systems approach that factored in human health and the associated economic benefits, according to Gao.

Gao's systematics research group—which uses modeling to understand complex global challenges in engineering, business, societal well-being and sustainability—is uniquely positioned for such a task.

"A transportation engineer cannot address these questions," Gao said. "Environmental science cannot address these questions. A health researcher cannot address these questions. However, this transdisciplinary group can do this."

Pan, Fulton and Gao built an integrated assessment system that included a technical-economic mobility model, a chemical transport model and a health impact assessment tool. Then they projected the vehicle stocks, distance traveled, energy usage and carbon dioxide emissions in the continental U.S. through 2050, and quantified the impacts of changing emissions on concentrations of fine particulate matter in the atmosphere, as well as the ensuing health and

economic benefits of populations in 10 major metropolitan areas.

Their simulations show that, depending on how widely the three "revolutions" are adopted, reductions in emissions from passenger travel could prevent between 2,300 and 8,100 premature deaths annually in the U.S. in 2050.

The largest number of prevented deaths coincided with large metropolitan areas, such as Los Angeles and Chicago. At the state level, California, Texas, New York, Ohio and Florida would see the largest decreases in premature mortality.

The associated economic benefits could range from $24 billion to $84 billion annually.

The study hangs on a number of assumptions and uncertainties. After all, driverless cars are not yet commercially available, and sales of electric vehicles lag far behind conventional gas guzzlers.

"Another key finding is that for carbon mitigations and health benefits, vehicle electrification is by far the most important piece, followed by shared mobility (ride-sharing) and then automation, " Pan said. "The net energy impacts of self-driving vehicles are highly uncertain and automation alone may not dramatically affect energy use, emissions or vehicle-related pollution. "

A complicating factor is that the efficiency improvement and projected cost reduction from automation could actually lead to increased travel and offset other gains.

"If we automate the vehicles, you might make the transportation system more efficient, but probably more people will travel longer distances," Gao said. "So there is a balance, there is a trade-off."

The study concludes that policymakers can help encourage the transition to electric vehicles and boost ride sharing, for example, by issuing tighter fuel economy standards, creating economic incentives for shared mobility and investing in charging infrastructure and technological developments.

A future of autonomous flying taxis

Of course, actually creating such transportation innovations is not possible without first determining their viability.

Another research project from Gao's lab—published this summer in "Transportation Research Part A: Policy and Practice"—explores the feasibility of an airport shuttle service that uses autonomous flying taxis as a means to mitigate urban congestion. The paper's lead author is Emily Lewis '20.

"While you are stuck in traffic from JFK [International Airport] to Manhattan, have you ever thought, oh, I wish I could be a bird, just to fly there. Actually, that dream is not too far away," said Gao, who directs Cornell's Center for Transportation, Environment and Community Health. "But how do you even architect a whole system, from the technology to market prediction and to operation? Would such an idea make economic

Reductions in emissions from passenger travel could prevent between 2,300 and 8,100 premature deaths annually in the U.S. in 2050.

Continued on page 18

FIELD MEMBERS INGRAFFEA, TESTER PARTICIPATE IN EARTH SOURCE HEAT OPEN HOUSE

An unremarkable gravel parking lot just off campus will soon house one of Cornell's most important living laboratories.

Welcome to the Cornell University Borehole Observatory—known as CUBO.

By summer 2022, the university plans to drill a 10,000-foot hole to verify whether conditions underground will allow clean, reliable and renewable Earth Source Heat—Cornell's name for direct heating with geothermal liquids—to warm the entire Cornell campus during the winter and help reduce the university's carbon footprint to zero.

The first important step is drilling this exploration well to confirm the technical viability and ensure the safe operation of the system.

About 80 students, faculty, staff and Tompkins County neighbors learned all about Earth Source Heat and how it would work at an open house hosted by the university on Nov. 9 in that parking lot.

"Cornell has been advancing research, monitoring and modeling for years," said Sarah Carson Zemanick, director of the Campus Sustainability Office. "This open house, and the interactions with those Cornellians involved, helped bring Earth Source Heat out of our labs and into a tangible and exciting reality for the community."

The test borehole aims to understand Earth Source Heat's viability and safety prospects. At the surface, the diameter of the hole will be about the size of a hula hoop. The sides of the hole will be encased in cement and steel, and will narrow as it deepens. When the hole reaches 10,000 feet—about two miles below the surface—its diameter will be about 8 inches, the size of a small frying pan. For perspective, the hole's depth equals more than seven Empire State Buildings.

At the open house, students and other community members crowded to hear answers at all five round-robin stations.

Linda and Buzz Lavine, from Dryden, NY, peppered Cornell geologist Ole Gustafson, Ph.D. '20, of Facilities and Campus Services, with questions about the physical borehole. Linda Lavine asked, "How long will it take to drill the hole?"

Engineers expect it takes about two months to drill a well down to 10,000 feet, where the Earth's temperature approaches nearly 200 degrees Fahrenheit—close to water's boiling point, Gustafson replied. He said that the CUBO well drilling operation will take a bit longer, since he, along with engineering and geology professors, will want to extract a lot of data during the test's drilling stages.

Terry Jordan, right, and Patrick Fulton, professors in the Department of Earth and Atmospheric Science, explain Earth Source Heat at the open house Nov. 9. . (Jason Koski/Cornell University)

If this initial borehole test confirms the right subsurface conditions, Cornell may propose a demonstration: Two new wells would be drilled so that hot subsurface water can be extracted from one well and returned down a second well for reheating by the Earth.

At the surface, heat exchangers would transfer the warmth of the hot fluid from the subsurface to another loop of water to circulate around campus and warm the buildings.

Local environmental scientist Noah Mark, of the nonprofit Community Science Institute, attended the open house to learn more about the Earth Source Heat process and discuss the quality of the recirculating water.

With a long poster showing the borehole layers in hand, Terry Jordan and Patrick Fulton, professors of Earth and Atmospheric Sciences in the College of Engineering explained the strata to attendees. Anthony Ingraffea, the Dwight C. Baum Professor of Engineering Emeritus,

never paused talking to the large crowd at his station. Also answering questions were Jeff Tester, professor of sustainable energy systems in the Smith School of Chemical and Biomolecular Engineering, and Steve Beyers, the lead Earth Source Heat engineer with Facilities and Campus Services.

Jacob Feit '22, who studies environmental policy and governance in the College of Agriculture and Life Sciences (CALS) and is the executive vice-chair of the Cornell Student Assembly, said testing the borehole concept was a good idea. "As students, we want to see Cornell commit to being as sustainable as technologically possible," he said. "This initiative accomplishes that while additionally establishing energy independence."

Danielle Bucci '23 and Jay Sangwan '23 stayed well past sunset and asked Sarah Brylinsky, assistant director of the Campus Sustainability Office, if this form of heat harmed the environment. Brylinsky said Earth Source Heat poses very little ecological disturbance. "There's no taking down trees or disrupting the environment," she answered.

Sangwan, a biology and society major (CALS), recognized carbon's impact on campus, but was not conversant on the Earth Source Heat idea. After attending the open house, he said, "This is a revolutionary concept."

Bucci, an environmental and sustainability major (CALS) said of combining Earth Source Heat and Lake Source Cooling: "There are really no environmental drawbacks and the environmental risks are low," she said. "Cornell is the only university in the Northeast doing this."

Carson Zemanick said she was delighted with the crowd's genuine curiosity and well-informed questions. "For Cornell to become more sustainable, I think there is a growing understanding that sustainability isn't a one-size-fits-all strategy," she said. "We're showing how important it is to develop and deploy game-changing solutions in a global context."

By Blaine Friedlander

Transoirtation innovations, from page 16

sense at all?"

The study focuses on the concept of urban air mobility—essentially a transportation service for low-altitude airspace in metropolitan areas that features autonomous unmanned aerial vehicles.

Gao's team—which included co-authors Jesse Ponnock '20, Qamar Cherqaoui '20, Scott Holmdahl '20,Yus Johnson '20 and Alfred Wong '20—focused on the three busiest airports in the U.S.: Atlanta, Los Angeles and Dallas.

They used a holistic, system-architecture analysis to identify each area's key stakeholders and the goals that meet their needs, such as fleet management, infrastructure, traffic control, safety, user experience, financial viability and performance. The modeling also took into account the relationships between annual profit, mean time between safety incidents, upfront costs and the number of passengers shuttled per day.

"Because of its geographic, meteorological and also demand factors, Los Angeles turns out to be the best case for a pilot city," Gao said.

The analysis identified wealthy commuters, long-distance commuters, business executives, event attendees, emergency transportation and vacationers as potential early adopters of an air mobility system.

What would such a system actually look like from a passenger's perspective? It might not be too different from the ride-sharing services of today. The analysis recommended the system use FIFO (first in, first out) queuing and a smartphone interface for passengers, which may sound familiar to anyone who has ever hailed an Uber on their phone.

Also recommended: a hybrid energy source that incorporates electric energy for the autonomous vehicles.

But vehicles and apps are only part of it. For an air mobility system to become a reality, it would need the infrastructure to support it.

"This is not actually as mature as electrification or even automation," Gao said. "This is even further away down the road. We are not comparing urban air mobility to other modes or arguing this is a better mode. We're just saying that now, given the interest, first you need to be able to architect this. And then you will have a better sense about cost."

By David Nutt

SYSTEMS PH.D. ALUM SELECTED AS INTEL FACULTY FELLOW

Faisal Alkaabneh Ph.D. '20, the first graduate of Cornell Systems' doctorate program, was selected an Intel Faculty Fellow for 2021-22.

"This is a great opportunity for us since it will give us access to Intel's subject expert matter in software development as well as establish a relationship with Intel," said Alkaabneh, who is an assistant professor in the Department of Industrial and Systems Engineering at North Carolina A&T State University in Greensboro.

Professor Alkaabneh's winning proposal, titled "AI-Based Tool for Social Good: Optimizing Food Allocation and Inventory Management at Food Banks," aims at developing a novel and innovative approach to using cloud computing, visualization techniques, analytics, and artificial intelligence (AI) tools for social good.

"Specifically, this research award will contribute to the advancement of food bank operations efficiency and social welfare by developing a framework for optimizing resource (i.e., food) allocation and inventory management at food banks in an integrated manner in uncertain environment," Alkaabneh said.

"Effective mitigation to the threat of food insecurity, one in eight Americans is food insecure including 13 million children, requires food banks to substantially increase the effectiveness and efficiency of their food allocation operations," he added.

In 2017, Professor Alkaabneh, under the supervision of Cornell Systems Engineering Professor H. Oliver Gao, started collaborating with the Food Bank of the Southern Tier (FBST), located in Elmira, NY, to help optimize food allocation and inventory management operations, taking into account effectiveness, efficiency and equity performance measures. Since then they have been recruiting Cornell computer science graduate students to build a website that translates their research into a practical tool. At the end of 2020, they had a pilot platform that was fully functioning and can be used by food bank personnel and recipients (e.g., food insecure households, agencies, etc.).

Professor Faisal Alkaabneh Ph.D. '20 of North Carolina A&T State University, has been selected an Intel® Faculty Fellow for 2021-22.

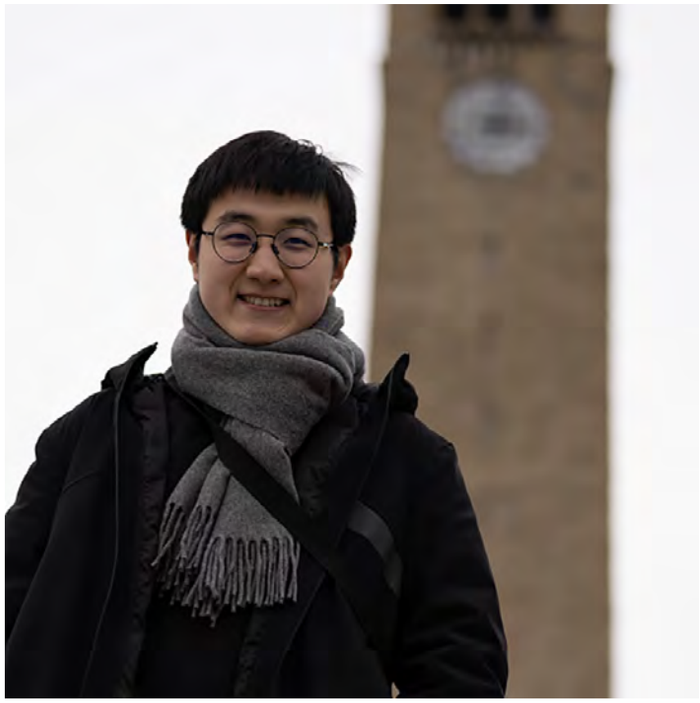
SYSTEMS PH.D. STUDENT NING ZHAO'S PAPER SELECTED RUNNER-UP AT PRES'21

Systems Ph.D. student Ning Zhao recently took runner-up honors for the De Gruyter Best Paper Award at the PRES'21 conference, held October 31-November 3 in Brno, Czech Republic. Zhao's paper, titled "Unit Commitment under Uncertainty using Data-Driven Optimization with Clustering Techniques," was co-authored by Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering.

Zhao's paper proposes a novel data-driven adaptive robust optimization (ARO) framework for the unit commitment (UC) problem integrating wind power into smart grids. By leveraging a Dirichlet process mixture model, a data-driven uncertainty set for wind power forecast errors is constructed as a union of several basic uncertainty sets. Therefore, the proposed uncertainty set can flexibly capture a compact region of uncertainty in a nonparametric fashion. Based on this uncertainty set and wind power forecasts, a data-driven adaptive robust UC problem is then formulated as a four-level optimization problem.

A decomposition-based algorithm is further developed. Compared to conventional robust UC models, the proposed approach does not presume single mode, symmetry, or independence in uncertainty. Moreover, it not only substantially withstands wind power forecast errors, but also significantly mitigates the conservatism issue by reducing operational costs. Zhao also compared the proposed approach with the state-of-the-art data-driven ARO method based on principal component analysis and kernel smoothing to assess its performance. The effectiveness of the proposed approach is demonstrated with the six-bus and IEEE 118-bus systems. Computational results show that the proposed approach scales gracefully with problem size and generates solutions that are more cost effective than the existing data-driven ARO method.

Zhao received a B.Eng. degree in automation from the University of Electronic Science and Technology of China in 2012, and his M.S. degree in control science and engineering from Tsinghua University in 2015. He is currently working toward a Ph.D. in systems at Cornell. His research interests include data-driven optimization under uncertainty and machine learning.



Systems Ph.D. student Ning Zhao earned runner-up for the De Greyter Best Paper Award at the PRES'21 conference held in the Czech Republic.

PH.D. STUDENT'S INTERESTS IN AGRICULTURE AND TECHNOLOGY LEAD TO THREE-YEAR FELLOWSHIP

Shiang-Wan Chin, a systems doctoral candidate at Cornell University, has been selected as a Rockey Foundation for Food and Agriculture Research (FFAR) Fellow for 2021-24.

"Throughout my life I've found three reoccurring themes: entrepreneurship, food security, and adventure-seeking," said Chin, who is sponsored by Microsoft and works closely with Dr. Ranveer Chandra, Managing Director for Microsoft Research for Industry. "During my undergraduate education at the University of California, Davis, I built my first startup, 'Brit's Bites', where I produced protein bars to solve my own problem of not having time and money."

Chin's research interests lie at the intersection of agriculture and technology and seeking to understand research as it connects to policy and social systems, and to startup ventures that bring research to fruition. With these goals in mind, he started "farmVal" from a 48-hour hackathon along with five others with the vision of bringing soil lab testing out of the lab and online.

"From my background in agriculture economics at UC Davis, business at Deloitte, and engineering at Cornell, I seek to combat food insecurity through research and action on Cornell's campus and hopefully around the world," said Chin. "Working with the Microsoft FarmBeats platform and new networking technologies my system is designed in a modular manner to permit differing use cases and optimization goals for the benefits of various stakeholders."

After graduating from UC Davis, Chin joined Deloitte in the Silicon Valley, working with blockchain clients at the height of the initial coin offering bubble in 2017. Seeking a deeper level of understanding of the technology, he left Deloitte to enroll in Cornell's systems engineering M.Eng. program. After earning his M.Eng., he decided to pursue a Ph.D. in systems with a focus on computer and data science.

Shiang-Wan Chin has earned a three-year fellowship from the Rockey Foundation for Food and Agriculture Research.

The Rockey FFAR Fellows Program was established to provide professional development and career guidance to the next generation of food and agriculture scientists across the Foundation for Food and Agriculture's challenge areas and strategic initiatives. The consensus among employers is that U.S. universities could better prepare a career-ready STEM workforce by breaking down the disciplinary silos and increasing the focus on professional development and "soft-skills," which would result in more well-rounded graduates. By providing early career support to graduate students, the program cultivates supportive relationships between graduate students and industry, government and NGO peers to equip students with the skills needed to facilitate their transition to the workforce and prepare future leaders for food and agriculture.

The Rockey FFAR Fellows Program is led by the academic programs office at the College of Agriculture and Life Sciences at North Carolina State University.

Cornell Engineering
Systems Engineering
601 Frank H.T. Rhodes Hall
Ithaca, NY 14853-3801

Systems M.Eng. alumna Renee Frohnert '19 (back center) competed on Baking Impossible, a Netflix original baking competition. See page 3 for more on Renee's experience.