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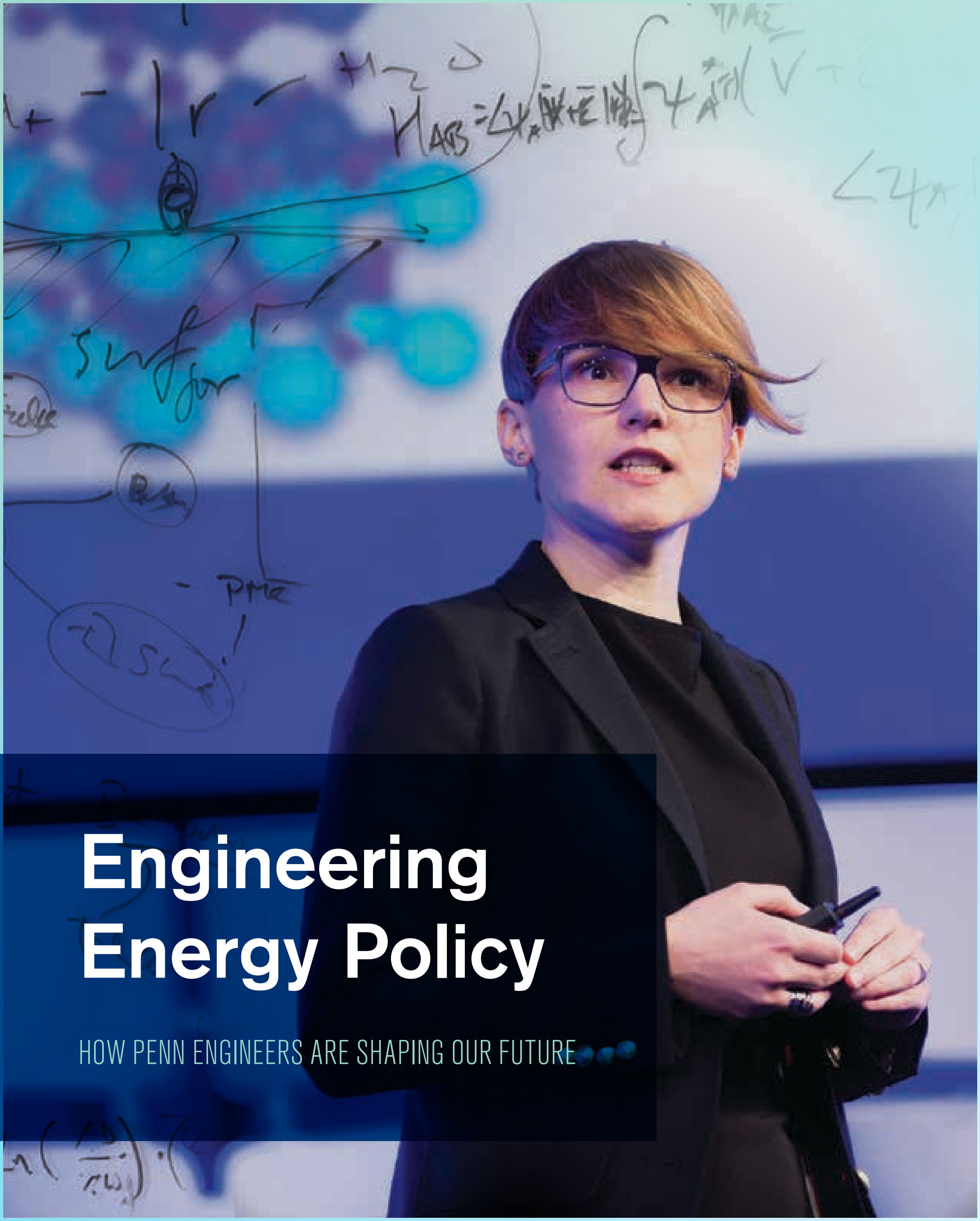


Engineering Energy Policy

HOW PENN ENGINEERS ARE SHAPING OUR FUTURE

Kleinman Center for Energy Policy

LETTER FROM THE DIRECTOR

Mark Alan Hughes
Founding Faculty Director
Kleinman Center for Energy Policy

Energy represents a set of growing challenges—from climate change to global conflict to widening inequality—that demand expertise from many disciplines and practices. It is no surprise, therefore, that Penn's commitment to integrating knowledge for good is cultivating something of a renaissance of energy research at the University. Faculty and student researchers come together in new efforts such as the Vagelos Institute for Energy Science and Technology, the Kleinman Center for Energy Policy, and the Vagelos Integrated Program in Energy Research. The result is discovery and innovation that are making an impact.

At the Kleinman Center, we know that good policy builds on basic science and applied technology. Most of our work requires the partnership of scientists and engineers. And that is the vision behind this book.

Engineering Energy Policy explores energy-related research happening next door to us on campus—in the labs of some of the world's most innovative engineers. From Nader Engheta's wave-powered computer to Shu Yang's kirigami cooling skins, today's working prototypes can provide critical guidance for tomorrow's energy policies. At the same time, today's policy innovations can help accelerate tomorrow's commercial deployment of new technologies.

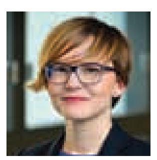
In partnership with the School of Engineering and Applied Science, we take the opportunity in this publication to celebrate the great work of our engineering colleagues while highlighting their energy policy implications.

Solutions to the world's most pressing energy challenges are inherently trans-disciplinary. This is one of Penn's great advantages, as a world-class university that celebrates collegiality and integrating knowledge as virtues. In this publication, we focus on connections between engineering and energy policy. In subsequent publications, we will explore energy policy connections with other schools and disciplines.

A special thanks to two deans who value this interdisciplinary approach: Fritz Steiner, dean of the Stuart Weitzman School of Design and Vijay Kumar, dean of the School of Engineering and Applied Science. Thank you for supporting collaboration between schools, prioritizing energy research, and raising Penn's visibility and impact in the energy space on and off campus.

Featured Researchers

A special thanks to Diana Lind for researching and writing these profile pieces.



Aleksandra Vojvodic
Associate Professor of Chemical and Biomolecular Engineering

Raymond Gorte
Russell Pearce and Elizabeth Crimian Heuer Professor of Chemical and Biomolecular Engineering, Professor of Materials Science and Engineering

John Vohs
Carl V. S. Patterson Professor and Chair of Chemical and Biomolecular Engineering

A CARBON-FREE SYNTHETIC FERTILIZER

The Haber-Bosch process for synthesizing ammonia transformed our agricultural system in the early 20th century. But today's process uses 1 to 2 percent of global energy each year. Three engineers are exploring zero-carbon ways to meet the world's growing fertilizer needs.

The Haber-Bosch method is "one of the most engineered processes" in the world, Professor Aleksandra Vojvodic says. It's how we make most industrial fertilizers—by creating ammonia from nitrogen and hydrogen with a metal catalyst under high pressure and heat.

But the Haber-Bosch process, first implemented in 1913, is also ripe for disruption.

It's an energy-intensive process that involves burning methane. Despite the longstanding use of this tried-and-true method, Vojvodic and fellow engineering professors Ray Gorte and John Vohs, are researching ways to replace it with a cleaner, greener process.

The problem lies not only in the chemistry of synthesizing ammonia; but in the need for an industrial scale process that can compete with Haber-Bosch. "We need it fast, we need it cheap, and we need a lot of it," Vojvodic says of the demand for fertilizer. Ironically, the Haber-Bosch process serves so many needs well, except for those of the planet.

Vojvodic and the Gorte-Vohs teams are approaching the problem differently. Vojvodic is focused on finding new materials that serve as catalysts. Because she conducts all her experiments virtually, with computations, she can sort through thousands of potential materials using algorithms. Her program can solve quantum mechanical equations depending on the chemistry. "It's like a puzzle," she says, describing the effort to match potential materials to the chemical reaction.

> "We need it fast, we need it cheap, and we need a lot of it."
>
> —ALEKSANDRA VOJVODIC

Gorte and Vohs are trying to synthesize ammonia using fuel cells. The concept is to bring water on one side, nitrogen on the other, and with electricity make ammonia. "Almost all of the work up to date has focused on trying to come up with new electrolytes to do that. What's novel about the approach we're taking is we're arguing the electrolyte is irrelevant. It's really the electrode catalysis that one has to focus on."

The Haber-Bosch method is enormously energy intensive—it consumes roughly 3 to 5 percent of the world's natural gas, and 1 to 2 percent of the world's energy supply. If a better method could work at scale, it would have a tremendous impact across the globe.

"If one can come up with a different way to make ammonia that uses solar energy for example, it changes the equation," Gorte says. "That's an example of how new technology can lead to policy decisions."

POLICY CHALLENGE

The 2015 Paris Climate Agreement recognizes that we have a "fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change." Fertilizer helps provide food security, but with enormous environmental impacts. Organic fertilizers avoid burning fuel, but are pricey, still release carbon, and produce lower yields.

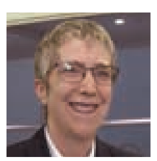
THE NUMBERS

Following the discovery of the Haber-Bosch process, unlimited synthetic fertilizer improved land productivity by approximately 400 percent and our food system now supports a 5x increase in population.

FURTHER READING

Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production (MIT Press), by Vaclav Smil

Photo: iStock.com/Patiwit



Karen Winey
TowerBrook Foundation Faculty Fellow and Professor of Materials Science and Engineering, Professor of Chemical and Biomolecular Engineering

BUILDING A LIGHTER BATTERY WITH POLYMERS

Electrifying the transportation sector is necessary to decrease global oil consumption and reduce the use of fossil fuels. By developing innovations that can improve efficiency, reliability, safety, durability, and affordability, Karen Winey is building the road to a fossil-free future.

Professor Karen Winey came to develop new kinds of polymers that could transform car batteries—as well as fuel cells and water purification—out of pure scientific curiosity. "There were unanswered questions about acid- and ion-containing polymers. What are their nanoscale structures and transport properties? If we changed the polymers, could we alter their arrangement and improve properties?" she wondered.

Winey is designing new kinds of polymers that will allow ions to move through them, namely solid polymer electrolytes (SPEs). Her group has already demonstrated that this new polymer design can have double the proton conductivity relative to a leading polymer. Extending this success from

proton transport to ion transport is their current focus, so as to revolutionize the lithium-ion or sodium-ion batteries typically used in electric vehicles.

The problem with lithium or sodium batteries is that they're made of flammable liquids. While the liquid itself isn't big or heavy, the extra circuitry and safety housing that ensures that the liquid doesn't get too hot or pose other safety hazards tends to be.

Winey's idea is to replace the liquid with a plastic. "If we could do that, it would be safer. It would be lighter weight, because you could reduce all that weight associated with safety housing," Winey explains. A lighter battery in cars, or even aerospace applications, could increase their energy efficiency.

> "Materials innovation and integration is slow. People say it takes 25 years to go from a new material idea to putting it into large-scale production. I'm really hoping that we can accelerate that pace."
>
> —KAREN WINEY

The proton conductivity results from Winey's NSF-funded research were published in a paper in *Nature Materials* in May 2018. Now she's working to extend their insights to ion conductivity. Once she's done that, she hopes to engage a major industry player to commercialize these new materials.

That said, this work takes time. She's already been at this project for five years. "Materials innovation and integration is slow," she says. "People say it takes 25 years to go from a new material idea to putting it into large-scale production. I'm really hoping that we can accelerate that pace."

If batteries can be safer and cheaper, we could further incentivize the conversion from fossil fuels to renewables. "If you eliminate the flammable liquid, you're going to increase the energy density, even if you don't change anything else," Winey says.

Karen Winey in front of the Dual Source and Environmental X-ray Scattering (DEXS) instrument, which her lab uses to test the properties of polymers.

POLICY CHALLENGE

Ten countries have pledged to pursue 30 percent electric vehicle (EV) sales by 2030; several European countries and the province of British Columbia have announced a ban on the sale of new internal combustion vehicles for as early as 2030; and in the United States, California and nine other states have adopted zero emissions vehicles programs. Yet, affordability, range, and limited lithium supply for batteries continue to be roadblocks for EV adoption.

THE NUMBERS

Globally, transportation accounts for 23 percent of our energy-related CO_2 emissions. In the U.S., the transportation sector accounts for almost a third of GHG emissions. But the penetration of electric cars is still limited to less than 1 percent of the global car fleet today. By 2030, projected EV stock could cut demand for oil products in a range from 2.5 to 4.3 million barrels per day.

FURTHER READING

2019 Global EV Outlook (IEA)

Robert Carpick
John Henry Towne Professor of Mechanical Engineering and Applied Mechanics

TRIBOLOGY: AN OBSCURE WORD WITH BIG IMPLICATIONS

Friction in engines and machinery results in energy losses, unnecessary carbon emissions, and lower productivity. By developing tribological solutions that address friction and wear and tear on moving parts, Rob Carpick unlocks energy efficiency gains in many sectors.

"Experts estimate that ten to twenty percent of global energy is wasted on friction," Professor Rob Carpick says, giving a glimpse of why tribology—the study of friction—is so integral to energy policy. Whether operating a wind turbine or a car engine, if there are moving parts, there is some amount of friction. Carpick is interested in the consequences of that wear and tear. Energy is not only spent on friction, but on producing replacement parts. Obviously the less often a part needs to be replaced, the more sustainable it is. And many new green technologies, like energy-efficient switches and friction energy generators, can be advanced by tribology research.

Carpick's research spans a number of areas, from studying how to reduce energy consumption in engines, to working with the Department of Defense on improving heavy vehicle efficiency in high-stress gears, to looking at the friction in nanoscale mechanical computer switches, which could make computing much more efficient.

"I'm lucky because I'm able to work in a very fertile area—fundamental engineering and science—where there are all sorts of fascinating problems to pursue to satisfy my curiosity and contribute to long term development of knowledge. At the same time, it addresses immediate practical concerns of energy efficiency and use."

> "We're very excited about ways to enhance the tribology—and therefore enhance the efficiency—of the performance and range of electric vehicles and e-mobility."
>
> —ROB CARPICK

One particular focus area is electric vehicles and other forms of e-mobility, like scooters. "We're very excited about ways to enhance the tribology and therefore enhance the efficiency—of the performance and range of electric vehicles and e-mobility. We're not only talking about potentially reducing or even eliminating the carbon footprint of vehicles, but also enabling new technologies like hoverboards and robotic assisted mobility and wheelchairs."

Electric motors are quite efficient even with relatively basic lubricants and high amounts of energy losses due to friction. With continued research into improving the lubricants and tribology of e-mobility, Carpick envisions even greater efficiency.

While energy conservation is often driven by market dynamics, like oil prices, tribology has the potential to contribute to greater energy efficiency in power generation, advanced manufacturing, gas, aviation, and electronics. Tribology research can show how to achieve policy goals aimed at conservation, efficiency, and reducing greenhouse gas emissions.

Collaborating with government will be essential to the success of this work. "We've learned, in large part due to the Kleinman Center, how important it is to be aware of policy considerations," Carpick says. "Often policy incentives are the way that technological innovations will end up being applied."

POLICY CHALLENGE

Using tribology to improve the energy efficiency of existing technologies and deploy new energy technologies can produce economic and environmental benefits. Their adoption, however, is lengthy and may not happen without policy intervention. Low energy prices and a myopic view of future benefits are among the reasons that prevent a widespread and quick adoption. EPA and DOE regulations can facilitate the adoption of tribology technologies like emissions standards for engines, energy efficiency standards for manufactured products, and even energy performance indicators for manufacturing plants and products.

THE NUMBERS

Machine driven processes such as pumps, fans, compressed air, and materials handling and processing account for 68 percent of electricity use. Energy intensity in manufacturing in the United States decreased from 2010 to 2014 by 4.4 percent. The IEA reports that without the efficiency improvements that have been made in the industry and service sectors since 2000, energy use in 2017 would have been 20 percent higher.

FURTHER READING

Influence of Tribology on Global Energy Consumption, Costs, and Emissions by Kenneth Holmberg and Ali Erdemir

Jorge Santiago-Aviles
Associate Professor Emeritus,
Electrical and Systems Engineering

EXPLORING A SMART GRID SOLUTION FOR PUERTO RICO

"Electrify Everything" may be the most influential energy policy idea in the world today, and Jorge Santiago-Aviles is strengthening the smart grid backbone of that idea with innovations in distributed solar power.

When Hurricane Maria hit Puerto Rico, the initial force of the storm devastated structures and killed dozens of people, but its damaging effects worsened because of an island-wide power outage. It took nearly a year to fully restore electricity to all neighborhoods. More than a thousand deaths have been attributed to the domino effect of lost electricity, ranging from people unable to use medical devices such as respirators, to people unable to take their refrigerated medicines such as insulin.

These catastrophes only reinforced what had been known for quite some time: Puerto Rico needs a more resilient energy grid. Professor Jorge Santiago-Aviles believed that out of the tragedy of Hurricane Maria there was an opportunity to create a new smart grid built off of renewable energy. After all, "distribution was totally destroyed," Santiago-Aviles says. This idea of a smart grid also interested one of Santiago-Aviles's Ph.D. students who was interested in energy policy issues.

A native of Puerto Rico, Santiago-Aviles reached out to a friend who lived in the southwest part of the island and had photovoltaic panels on his roof. These grid-tied panels generated about 15 kilowatts of energy and were linked to software that produced a data file about the production of each individual panel. Using those data files along with data from the weather bureau about cloud cover in the region, and funding from the Kleinman Center for Energy Policy, Santiago-Aviles hired an engineering student who developed a model of the panels using artificial intelligence.

> "In what season will we have more cloud cover? In what part of the day we have more cloud cover? And how will the grid react?"
>
> —JORGE SANTIAGO-AVILES

"In what season will we have more cloud cover? In what part of the day will we have more cloud cover?" Santiago-Aviles wanted to know. "And how will the grid react?"

He found that there are some influences of renewables on the grid, and that they were larger than anticipated. In the United States the grid is faster, more modern, and has more stray capacity; in Puerto Rico smaller fluctuations had a bigger effect. That said, even such a small amount of photovoltaics could feed the grid during the day, a promising sign.

Today Santiago-Aviles estimates that approximately 20 percent of the island's energy comes from renewable sources, compared to "maybe 1 percent" before the hurricane. The new island-wide smart grid hasn't come to pass yet, due to a complicated political situation. But when the time comes, he hopes to provide models that shape Puerto Rico's energy future.

POLICY CHALLENGE

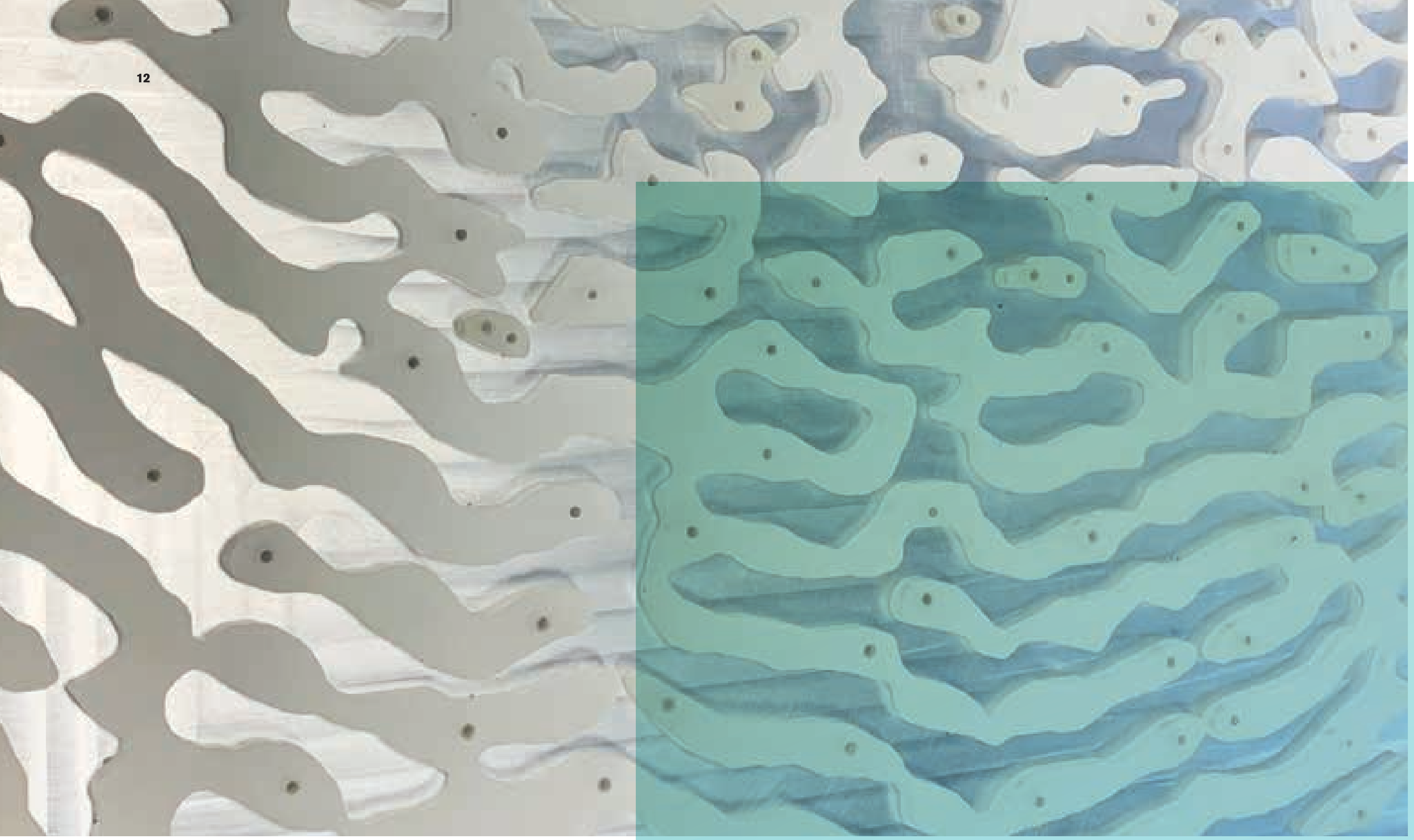
Throughout the world, critical interoperability standards, such as IEC 61850 and IEEE 1547, are being developed and applied. In 2017, 39 states took a total of 288 policy actions related to the smart grid and its components—such as non-wire alternatives, rate reform, advanced metering, and integration of distributed resources like rooftop solar and energy storage. In Puerto Rico, where energy systems are being rebuilt, there is new law and emerging policy in the Commonwealth that has established an urgent agenda for a cleaner and more resilient grid.

THE NUMBERS

To complete a smart grid by 2030, the Congressional Research Service estimates that the U.S electricity industry will spend up to $46 billion. The remaining investment needs range between $260 billion and $526 billion.

FURTHER READING

Tracking Clean Energy Progress (IEA)



Nader Engheta
H. Nedwill Ramsey Professor of Electrical and Systems Engineering, Professor of Bioengineering, Professor of Materials Science and Engineering, Professor of Physics and Astronomy

Above: The inner workings of Engheta's analog computer.

BEYOND BINARY: POWERING COMPUTERS WITH WAVES

Nader Engheta and his research team have designed the first prototype of an entirely new kind of computer: one that runs off of light rather than electricity. Once brought to the nanoscale, this technology could run computations much more efficiently and quickly than any digital computer that could ever be designed with existing transistor technology.

"We love waves. We are passionate about waves. Electromagnetic waves, microwaves, optical waves," says Professor Nader Engheta, introducing the wave-matter interaction research that his group does. Engheta's passion for waves first arose as a child, watching his brother use a transistor radio. Now he applies waves to a variety of high-level research questions.

Engheta has designed a material that, when waves are sent through it, can solve equations or do analog computations. "We have done that theoretically and experimentally," he says.

This success is just the beginning though. Many phenomena in science and engineering can be written in integral equations, so if Engheta's material can solve equations, it has many potential applications.

"Whenever you have the possibility to compute something very fast and with small volume, it can be applied in many fields," Engheta explains. Think of all the disciplines that involve nanoscale circuits, such as healthcare and tech.

Engheta is ambitious about how far he can take this research. While the analog computing is groundbreaking, the next step is to see if the material can learn from the computations, essentially transforming from an analog computer to one that has artificial intelligence.

> "There's a very natural connection between this work and energy, as waves have energy."
>
> —NADER ENGHETA

And what if there were a way to do these computations with less energy? Computers were once large, energy-sucking machines. Nowadays, we tend to think of phones and laptops as relatively efficient, but their energy uses have been "offshored" in a sense, as huge amounts of energy are needed to power the servers for cloud-based computing. If Engheta's technology is faster, and uses less energy, it could contribute to a major energy savings.

"There's a very natural connection between this work and energy, as waves have energy." Engheta says. Indeed, the waves lose little energy in the computation process and could also be "recycled," resulting in ultra low power wave-based computing systems.

To get to this point will take time. That said, Engheta notes that he never would have believed 30 years ago that he could make calls across the world using a phone the size of a cigarette box. Perhaps some day those phones will be analog.

POLICY CHALLENGE

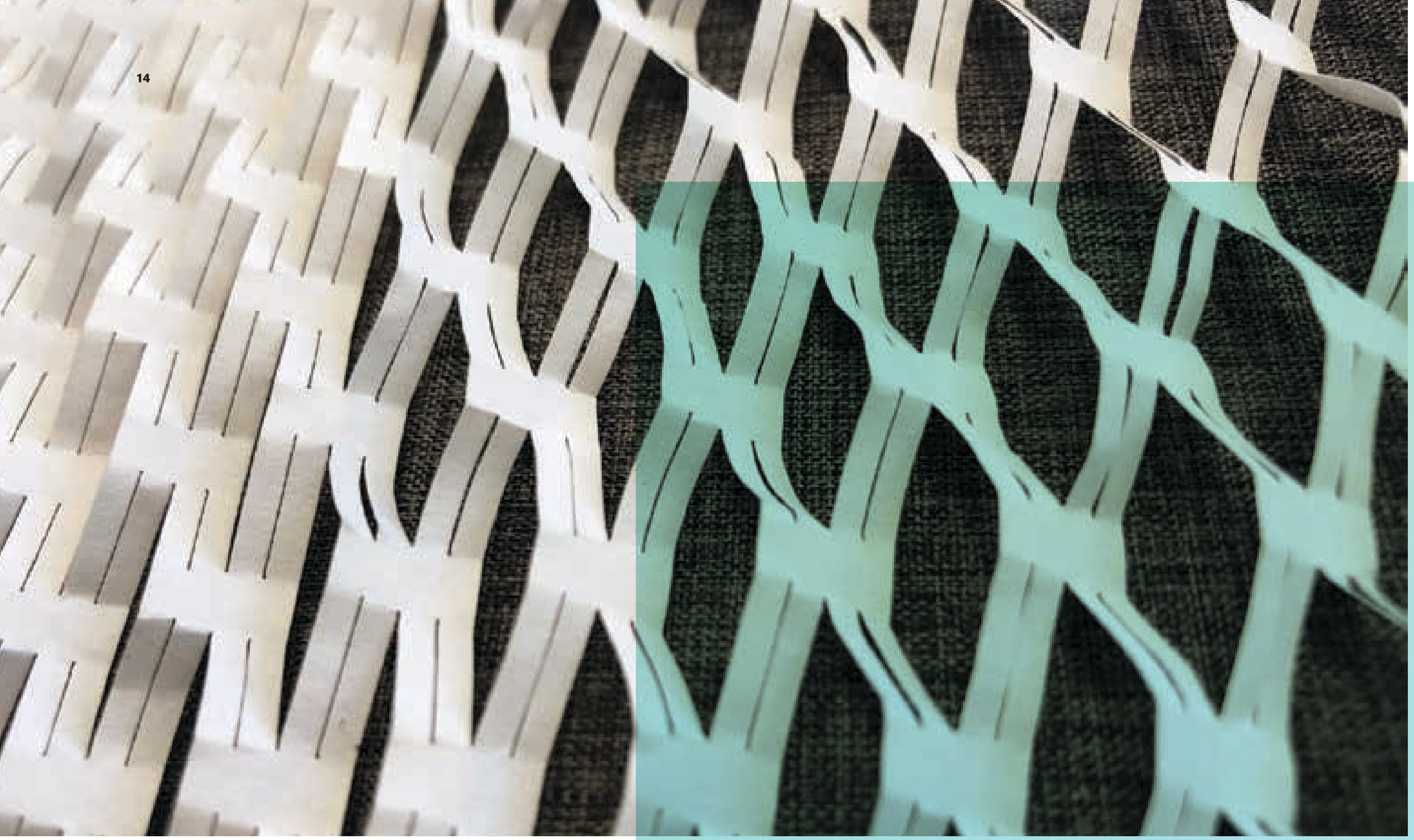
Renewable Energy Certificates or Renewable Portfolio Standards require that distribution and generation companies produce a certain percentage of clean or renewable energy. The problem with policies such as Renewable Energy Certificates and Renewable Portfolio Standards is that they are percentage measures of an ever increasing whole. They chase a moving target. Renewable percentage standards must constantly increase if they are to maintain emissions reduction targets in a growing energy system, or new breakthroughs in energy efficiency, such as wave-powered computing, must be made.

THE NUMBERS

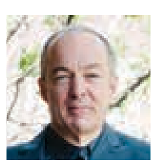
Computational energy demand is projected to increase exponentially over the coming decades. By 2025, the information, communication, and technology sector could use up to 20 percent of all electricity and emit up to 5.5 percent of the world's carbon. By 2040, this sector could consume as much energy as we use today across all sectors.

FURTHER READING

Total Consumer Power Consumption Forecast (Huawei Technologies) by Andrae Anders



Shu Yang
Professor of Materials Science and Engineering, Professor of Chemical and Biomolecular Engineering



William Braham
Professor of Architecture in the Stuart Weitzman School of Design

Above: A closeup of one of Yang's kirigami prototypes.

REDUCING ENERGY USE WITH 'BUILDING SKINS'

In the heavily regulated building sector, innovative materials face a major disadvantage: building codes. For this reason, and because climate change can't wait, Shu Yang is using approved materials in new ways to bring her self-cooling building skins to market.

Professor Shu Yang is motivated by having an impact. Originally focused on studying nanomaterials, she recalls attending a meeting at the Kleinman Center for Energy Policy about ways buildings could be more efficient and thinking: "This is my passion. I want to hear from other people what their problems or needs are, and then I can say, 'How can I help?'"

Yang's current research focuses on modulating solar gain through windows and other glass facades. When multiplied over the billions of buildings that could potentially benefit, her work has great scale.

Yang, and her collaborator, Professor William Braham (Stuart Weitzman School of Design), sought to create a "responsive facade"—a passive building envelope that responds to outside temperature and light without human intervention. Yang's approach is deeply influenced by observing the natural world. Whether looking at butterflies or a flower, Yang has always wondered, "Why do they have this particular coloring? Why do they behave this way? It's about the habitat." She notes how nature often comes up with the smartest approach to solving its own problems. Nature's cells are hexagons, for example, because this is the densest packing shape.

> "You can do great science, but if nobody is going to adopt it, what is the point?"
>
> —SHU YANG

While so many aspects of the natural world work in concert, most man-made buildings fight against nature. Yang sought to develop a product that better coordinates building and nature. Her responsive facade features a shade that has a motor connected to a bucket of water on the outside of the building. The bucket collects dew overnight, drawing the shades up. When the water evaporates throughout the day in response to heat and sunlight, the bucket becomes lighter, allowing the shade to drop down. "You want to be informed by biological systems but you don't want to copy them."

The shade's impact on the space is made more complex by its kirigami design. A variation of origami paper folding, kirigami is a Japanese style of cutting or folding paper to develop a pattern or design. While the kirigami technique is traditionally used to create art, here the technique is used to alter how light penetrates a window shade. "By cutting out a design, you can let the light in," Yang says. The cuts also allow a shade to be more flexible and stretch. "The question then is how can we make it responsive to temperature and light? And how much heat do you generate when you open or close the shade?" When you open a shade, it lets in light, infrared rays, and unwanted heat; when you close it, it blocks those elements.

Trained as a material scientist, Yang is working with Braham to study the shade's movements and consequences for a building's energy use. Slight changes to the kirigami design—such as variations in the shade's length, width, and geometry, tilted angles of the panels, or coatings—could allow the shade to reflect, absorb, or deflect light and therefore change the building's energy use.

Their next step is to work with policymakers or practitioners to understand how to implement the materials. Yang is working with materials that are already approved by building code, ensuring that they can be easily used by architects and developers. For Yang, ensuring that her work has real-world consequence is important. "Yes, you can do great science, but if nobody is going to adopt it, what is the point?"

POLICY CHALLENGE

The International Code Council sets the standard for electrical, plumbing, and mechanical codes, which are adopted by many countries and across the United States. In the U.S., these I-Codes are either adopted as state or local law. Because governments can add or alter these codes, developing universal solutions across jurisdictions is difficult.

THE NUMBERS

About 40 percent of energy consumed by buildings worldwide is for heating and cooling. The U.S. Energy Information Administration estimates that in 2018, electricity use for cooling the interior of buildings (space cooling) for both residential and commercial was about 377 billion kWh, or about 9 percent of total U.S. electricity consumption in 2018.

FURTHER READING

Global Trends in Urban Electricity Demands for Cooling and Heating (Elsevier)

Rahul Mangharam
Associate Professor of Electrical Systems and Engineering, Associate Professor of Computer and Information Science

ARTIFICIAL INTELLIGENCE FOR SMART BUILDINGS

Managing energy demand is essential in the complex global energy transition where price volatility is the norm, and Rahul Mangharam is making demand-side energy flexibility management a more powerful tool in energy policy.

At a time when climate change is producing extreme swings in temperature, energy prices themselves have grown wildly volatile. Professor Rahul Mangharam has seen instances in the summer when energy prices went from $32/MWh to $800/MWh—a 36x increase in price—in a matter of five minutes. In the winter during polar vortexes, the price can jump from $25/MWh to $2,680/MWh, and the grid requires the demand-side to become flexible.

Mangharam is interested in buildings because they consume the bulk of energy in the grid. And 70 percent of electricity is consumed by heating and cooling systems. "Our goal is to take buildings from not-so-smart on/off rule-based systems to electricity price-aware and adaptive smart buildings," Mangharam says.

For Mangharam, the big question is: "How can we transform buildings into aggregate flexible loads that adapt their usage to spikes in prices? As buildings are unique and complex, we bridge machine learning and control theory for low-cost and low-touch methods of controlling and aggregating building loads."

He's not just interested in making building operations more cost-effective, but in the climate consequences of buildings that can't adapt better to extreme weather. When there is a price spike, it's due to a grid operator turning on its peak-capacity systems—often these are old, coal-burning plants.

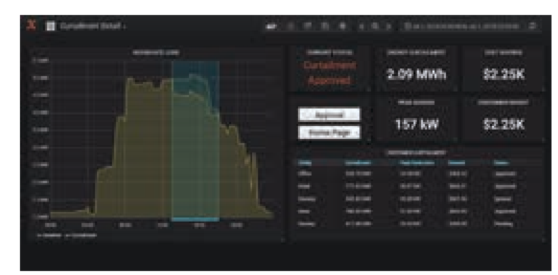
> "Our goal is to take buildings from not so smart on/off rule-based systems to electricity price-aware and adaptive smart buildings."
>
> —RAHUL MANGHARAM

For cities, universities, or other major property owners, these price spikes are extremely expensive. Penn, for example, has 217 buildings that altogether cost $28 million per year for electricity usage. In years past, if Penn went over capacity for, say, 30 minutes, the demand charge would be $720,000—and, the university's electric bill would be higher going forward to account for this peak usage.

"How can these buildings become responsive to this volatility?" Mangharam asks. The core of his research uses machine learning algorithms to capture a building's dynamics through hundreds of sensors already in the building. In a few hours, a data-driven model of the building is learned to predict future power consumption. This model is used to generate automatic control strategies to reduce the building's energy consumption, while guaranteeing thermal comfort.

"We are bridging machine learning and control systems for the demand-side of energy. Our algorithms continually evaluate how much energy flexibility a building has and automatically controls it for sustainable operations with budget certainty. From a budget standpoint, there's lower cost and more predictability. For facilities, less guesswork and more visibility. For occupants, more comfort. And for sustainability, there's a smaller carbon footprint," he says. This way, as the prices of energy go up, the building management system can respond in real time.

How smart is that?



The interactive analytics dashboard of Mangharam's system, which micro-grid operators use to compare real-time energy flexibility across their portfolio of buildings.

POLICY CHALLENGE

Public Utility Commissions in more than 30 states approved Demand Response (DR) programs, and utilities have enrolled at least 100MW of DR capacity. PJM, which manages the transmission market in 13 eastern and midwestern states, met over 4 percent of its 2018 committed capacity using DR.

THE NUMBERS

According to the International Energy Association, the buildings and building construction sectors combined are responsible for 36 percent of global final energy consumption and nearly 40 percent of total direct and indirect CO_2 emissions.

FURTHER READING

2018 Utility Demand Response Market Snapshot (SEPA)

Russell Composto
Howell Family Faculty Fellow, Associate Dean of Undergraduate Education (SEAS), Professor of Materials Science and Engineering, Professor of Chemical and Biomolecular Engineering, Professor of Bioengineering

POWERING CONVERSATIONS

The foundation of better energy policy is better communication between scientists and policymakers.

Professor Russell Composto's work wasn't always focused on climate change. But over his career researching polymer science and studying coatings, many of which had applications in reducing energy use, his primary focus evolved from advancing scientific knowledge to using science as a lever for fighting climate change.

Now he says: "For the rest of my life, I want to focus on how science and climate change could be better interconnected. Because we can't wait."

Composto's goal isn't just a better coating (although he's passionate about that, too). It's a completely different paradigm: Changing the way scientists and policymakers interface.

"We need to start talking among ourselves—the scientists and policymakers—so we both understand each other better," he says. How many policymakers can handily discuss thermodynamics? How many engineers know how to push

through a piece of legislation? Composto believes this lack of understanding is a challenge for crafting better energy policy.

Despite often having common goals of increasing energy efficiency and reducing energy use, scientists and policymakers rarely share the same language, knowledge, or experiences. As a result, Composto says, "There's a big gap between what we're doing in the laboratory and what's being promised."

Policies like the Paris Agreement, or even a city's sustainability plan, are based upon assumptions about how effective technologies can be. "Many times we can do these things at the laboratory scale, but as we translate them into the real world, there's 10 to 15 years of testing and scale up that needs to happen," he says.

"For the rest of my life, I want to focus on how science and climate change could be better interconnected. Because we can't wait."

—RUSSELL COMPOSTO

Policymakers risk overpromising and underdelivering because of a lack of nuanced expertise. For example, critics of the Green New Deal question the goal of moving the United States to exclusively "carbon-free" energy. While such an ambition sounds good, it excludes the use of nuclear energy and energy plants that burn fossil fuels but capture their emissions—two options considered essential to quickly bring down emissions. Since a policy is only as good as the science that supports it, policymakers' lack of scientific expertise can be problematic.

As a first step toward convening scientists and policymakers, Composto and colleagues from the Kleinman Center and Perry World House hosted a conference called REACT@Penn in January 2019. The event gathered scholars doing basic science at Penn, international collaborators from France and South Korea, and policymakers for discussions about interdisciplinary topics such as water, health, infectious disease transmission and how to collect and store energy. (REACT stands for Research and Education in Active Coating Technologies and is sponsored by the U.S. National Science Foundation and French National Research Agency.)

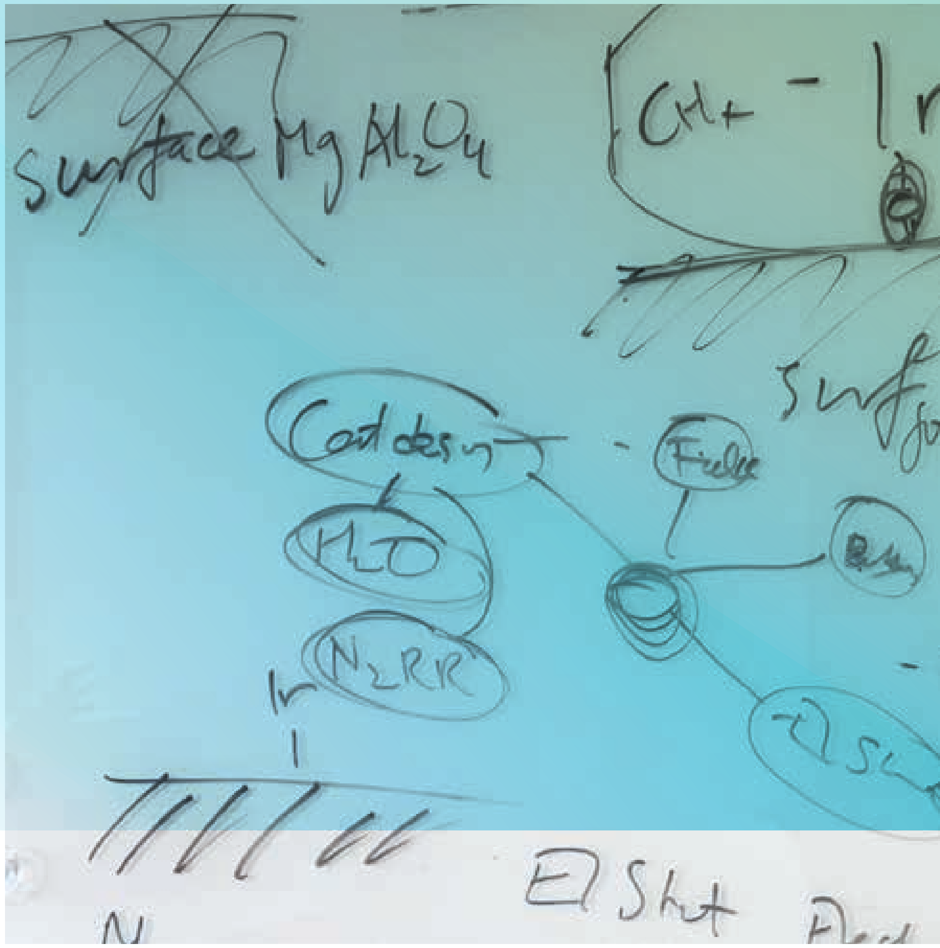
The event gave students a taste of what interdisciplinary connection looks like.

"A lot of our students are interested in going in the policy direction, but they just don't know how. They don't know the pathway," Composto says. In his role as Undergraduate Dean of Engineering, Composto says that a large percentage of students applying to Penn's engineering program write about "wanting to save the world" and climate change. After the REACT conference, students came up to Composto to say this was perfect exposure given where they want to take their career.

For Composto, the REACT conference was just the beginning of Penn's effort to educate what he calls "the future generation of scientifically literate policymakers that really understand thermodynamics." He believes Penn is in the perfect position to create a new curriculum that helps scientists learn more about crafting policy, and teaches policy students basic science. "There needs to be enough in common where they're actually in the same classroom, working together on case studies or projects where they're learning together," he says.

In addition to policy and science students, Composto sees a role for business students, as economic drivers play a major role in the way energy policy plays out. "Penn should be the place where this happens," Composto says. Such an interdisciplinary program "could make Penn quite unique," he adds.

For now, Composto is focused on helping students, not only with their studies but also with their climate activism. "I've always liked training students. That's always been my passion, as much as the science."



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